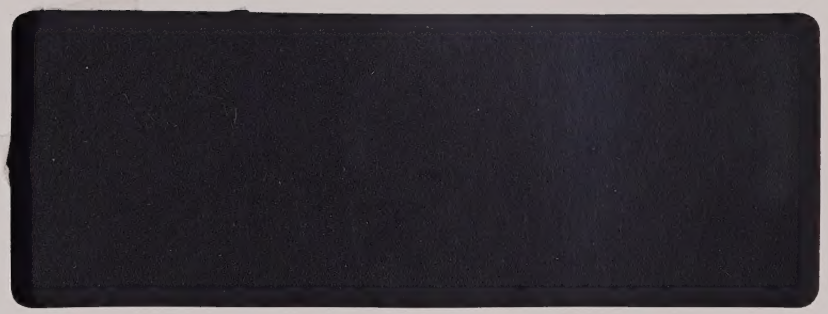
# INSTRUCTION MANUAL

# 5004

## DIGITAL MULTIMETER

RACAL-DANA



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# 5004
## DIGITAL MULTIMETER

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RACAL

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Within one year of purchase, Racal-Dana will repair or replace your instrument, at our option, if in any way it is defective in material or workmanship. All parts and labor charges will be paid by Racal-Dana Instruments. Just call Racal-Dana Product Service (collect) at (714) 833-1234 in U.S.A., Windsor (07535) 69811 in England or 027-7575 in France for assistance. We will advise the proper shipping address for your prepaid shipment. Your instrument will be returned to you freight prepaid.

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# FOR YOUR SAFETY

Before undertaking any maintenance procedure, whether it be a specific troubleshooting or maintenance procedure described herein or an exploratory procedure aimed at determining whether there has been a malfunction, read the applicable section of this manual and note carefully the WARNING and CAUTION notices contained therein.

The equipment described in this manual contains voltage hazardous to human life and safety and which is capable of inflicting personal injury. The cautionary and warning notes are included in this manual to alert operator and maintenance personnel to the electrical hazards and thus prevent personal injury and damage to equipment.

If this instrument is to be powered from the AC Mains through an autotransformer (such as a Variac or equivalent) ensure that the common connector is connected to the neutral (earthed pole) of the power supply.

Before operating the unit ensure that the protective conductor (green wire) is connected to the ground (earth) protective conductor of the power outlet. Do not defeat the protective feature of the third protective conductor in the power cord by using a two conductor extension cord or a three-prong/two-prong adapter.

Maintenance and calibration procedures contained in this manual sometimes call for operation of the unit with power applied and protective covers removed. Read the procedures carefully and heed Warnings to avoid "live" circuit points to ensure your personal safety.

Before operating this instrument.

1. Ensure that the instrument is configured to operate on the voltage available at the power source. See Installation section.
2. Ensure that the proper fuse is in place in the instrument for the power source on which the instrument is to be operated.
3. Ensure that all other devices connected to or in proximity to this instrument are properly grounded or connected to the protective third-wire earth ground.

If at any time the instrument:

- Fails to operate satisfactorily
- Shows visible damage
- Has been stored under unfavorable conditions
- Has sustained stress

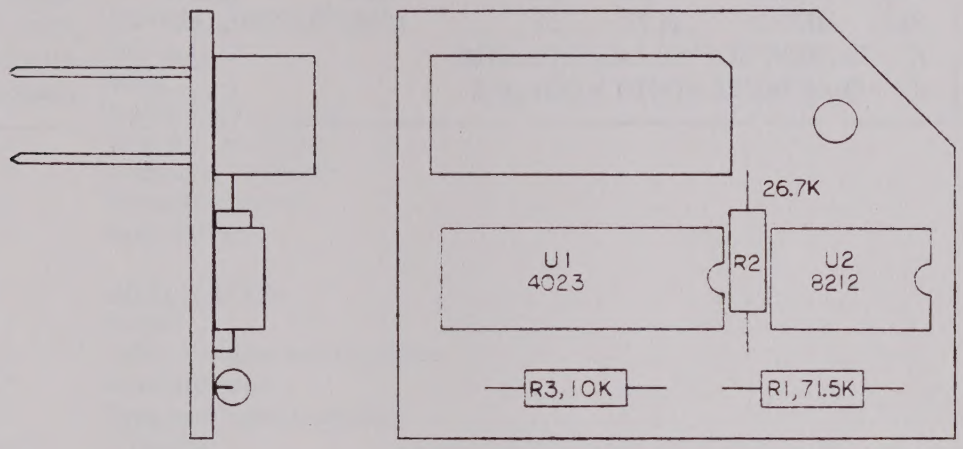
It should not be used until the performance has been checked by qualified personnel.

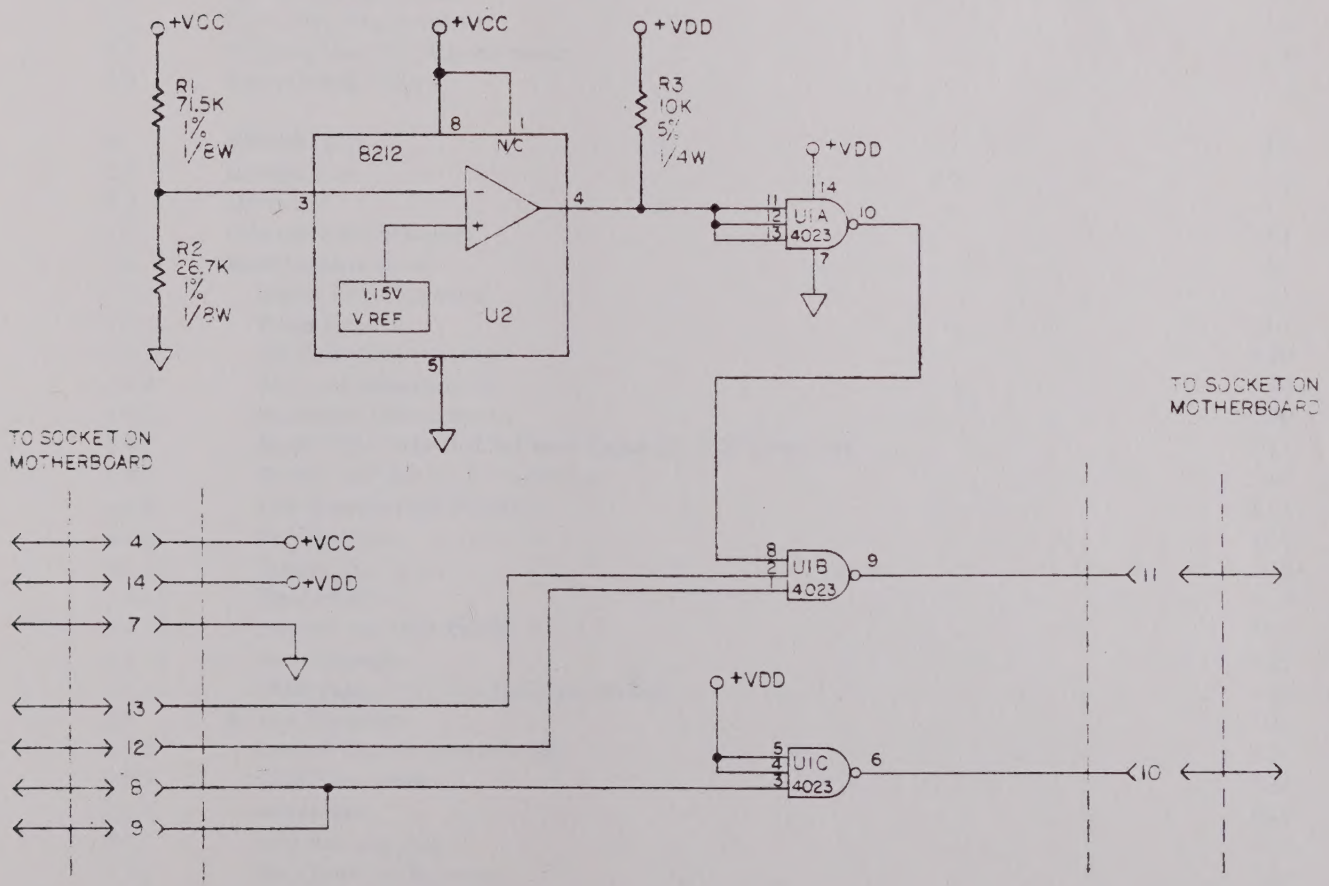
FOR YOUR SAFETY

# ERRATA SHEET

April 29, 1981

This unit contains a plug-in assembly, P/N 401683, which replaces U42 with the following:



401683 - PCB Assy, NON-VOL, PWR. DOWN

| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| R3 | 000103 | RES CARBON 10K 5% 1/4W | 81349 | RC07GF103J |
| R1 | 010643 | RES METAL 71.5K 1% 1/10W | 81349 | RN55C7152F |
| R2 | 010697 | RES METAL 26.7K 1% 1/10W | 81349 | RN55C267F |
| U2 | 230515 | IC MICROPOWER VOLTAGE DETECTOR | 32293 | ICL8212CPA |
| U1 | 230588 | IC CMOS TRIPLE 3 INPUT NANDGATE | 27014 | CD4023C |

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# SECTION 1 GENERAL DESCRIPTION

## 1.1 PURPOSE.

1.1.1 Racal-Dana prepared this Instruction Manual for the user. It supplies the operation procedures essential in optimizing the capabilities designed into the instrument, also, the Instruction Manual details the calibration and maintenance procedures required by technical personnel. These service procedures are necessary to obtain the maximum performance specified by Racal-Dana. It is recommended that the users and technicians read this manual before operating the instrument.

## 1.2 SCOPE.

1.2.1 The scope of this manual includes Racal-Dana product support, installation, operation, and maintenance guidelines pertinent to the instrument. The following subsections are included to support operation and maintenance activities: Installation, Operation, Theory of Operation, Maintenance, Drawings and Parts List.

## 1.3 PRODUCT SUPPORT GROUP.

1.3.1 The Racal-Dana Irvine complex maintains a complete Engineering laboratory, Field Engineers, service department and parts department to support the product commitment. Further support is provided by a network of area service centers and Field Representatives, the complete list appears on the last two pages of the manual. The warranty program declaration is presented in the forward section of this manual, also service personnel are available for service consultation.

## 1.4 ELECTRICAL DESCRIPTION.

1.4.1 The Racal-Dana Model 5004 microprocessor ($\mu$P) based digital multimeter (DMM) is a 5 1/2 digit auto-ranging multimeter. The basic functions include 5 DC volt scales ranging from 0.1 volt to 1 KV; 4 AC volt scales ranging from 1 volt to 750V, and 6 resistance measurement scales ranging from 0.1K ohm to 10,000K ohms. The chart in Table 1.1 represents the DMM function and ranges. For systems applications, the Model 5004 features an IEEE-488-1978 (GPIB) interface.

1.4.2 The DMM measurement process depicted in the block diagram Figure 1.1 consists of three major parts:

a) The Signal Conditioning section where the input signal is switched, scaled, attenuated, rectified and filtered under microprocessor control.

**Table 1.1 - DMM Function and Range**

| RANGE | FUNCTION | | |
|---|---|---|---|
| | DC | AC | OHMS |
| .1V | ▒ | | |
| 1V | ▒ | ▒ | |
| 10V | ▒ | ▒ | |
| 100V | ▒ | ▒ | |
| 1000V* | ▒ | ▒ | |
| .1KΩ | | | ▒ |
| 1KΩ | | | ▒ |
| 10KΩ | | | ▒ |
| 100KΩ | | | ▒ |
| 1000KΩ | | | ▒ |
| 10000KΩ | | | ▒ |

*1000 Volts DC; 750 VAC.

b) The Analog-to-Digital converter employs a Quantized Feedback conversion technique, to change the DC voltage into a representative digital signal.

c) The $\mu$P-based digital section translates the analog to digital (A/D) converter output to a numerical value for the instrument display and GPIB output that represents the value of the input signal. The digital section also provides function selection, range control, decimal placement and programming.

## 1.5 MECHANICAL DESCRIPTION.

1.5.1 The DMM physical configuration is outlined in Figure 1.2, a dimensional outline projecting the front and rear views from the top elevation. The front panel contains the keyboard switches, the LED display, and Input terminals. The rear panel contains Input terminals, 24 pin GPIB connector, GPIB address switch, two BNC connectors, 3 prong AC power plug and fuse.

## 1.6 POWER REQUIREMENTS.

1.6.1 The DMM is designed to operate from a wide range of AC line voltages and frequencies with 120 VAC and 60 Hz considered standard. The selectable multi-tapped primary winding will accommodate line voltages of 100,

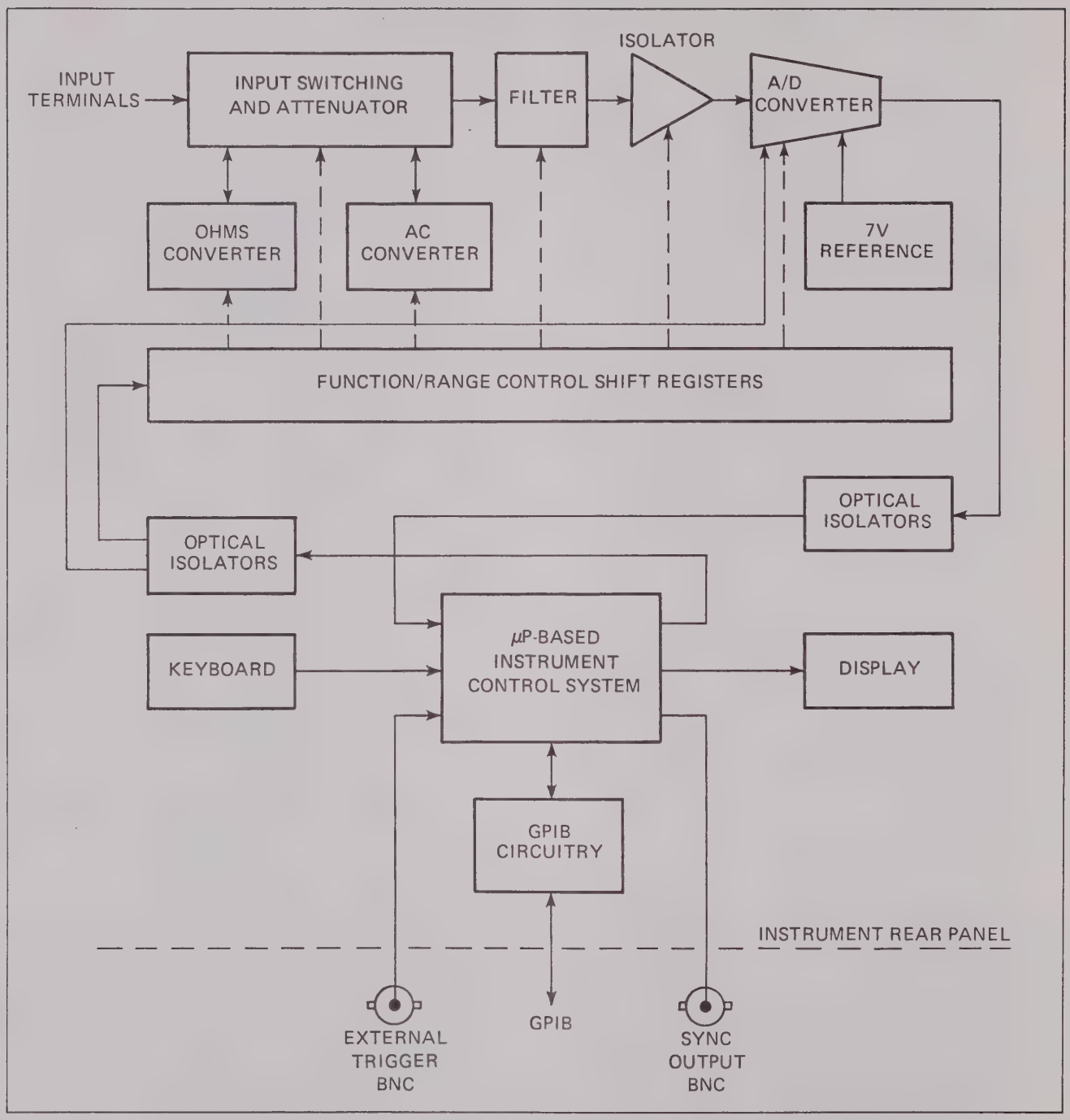



*Figure 1.1 - Model 5004 DMM Block Diagram*

120, 220, and 240 VAC ± 10%, 47 to 440 Hz. The installation, section 2 presents the AC line cord requirements, and the AC primary voltage selection instructions.

## 1.7 SPECIFICATIONS.

1.7.1 The published specifications for the Racal-Dana Model 5004 are listed in Table 1.2. These specifications establish the validation for the calibration and specification checks listed in this manual.

**Table 1.2 - Specifications**

| GENERAL SPECIFICATIONS | |
|---|---|
| **Power Requirements:** | 100, 120, 220 or 240 ± 10%<br>25 Watts maximum<br>60 Hz Standard<br>50 Hz Available |
| **Weight:** | 15 lbs. |
| **Dimensions:** | 3.5" Height x 19" Deep x 16.6" Wide |
| **Rack Mounting:** | Standard Corporate Package |
| **Warranty:** | Standard Warranty Statement |
| **Temperature Range:**<br>Operating<br>Storage | <br>0°C to 50°C<br>–40°C to +70°C @ 80% R.H. |
| **Humidity, Operating:** | < 75% RH; 0°C to 40°C<br>< 50% RH; 40°C to 50°C |
| **Vibration, Operating:** | Meets Class 4 requirements of MIL-T-28800B |
| **Fuse:** | .5 Amp "Slo-Blo" (115V)<br>.25 Amp "Slo-Blo" (220V) |
| **Battery:** | A 3.0V lithium battery provides power for the non-volatile memory whenever the DMM is turned off. Battery life is 3 years minimum at a 50° C ambient temperature. Battery is not rechargeable. |

| DMM GENERAL | |
|---|---|
| **Data Display:** | 5 full decades plus overrange digit in 5-1/2 digit mode. 4 full decades plus overrange digit in 4-1/2 digit mode. |
| **Overload Indication:** | Display reads "OL". |
| **Warmup Time to 24 hr. Specifications:** | 2 hours. |
| **Warmup Time to Fully Stabilize to 6 mo. Specifications:** | 1 hour. |
| **Maximum Common Mode Voltage:** | 1000V peak or DC, Guard to case.<br>250V Peak or DC, Analog Common to Guard. |
| **Overrange:** | 100% overrange with full accuracy on all ranges and functions except 1KV (1000V DC or 1100V peak AC max.) |
| **Ranging:** | Autorange standard Upranges at approx. 225% of range.<br>Downranges at approx. 20% of range.<br>Manual range standard. |

| DMM GENERAL continued | | |
|---|---|---|
| **Read Rate: * (Internal Trigger, External or GPIB Trigger)** | 4 Readings/Sec in 5-1/2 digit mode (60 Hz instrument).<br>3.3 Readings/Sec (50 Hz instrument). | |
| **Timeout Delays:**<br>These delays are inserted between each ranging required during autorange and before the final reading. | DC<br>.1 KΩ to 1000 KΩ<br>10,000 KΩ<br>AC<br>Any function with FILTER selected | 30 mS<br>40 mS<br>300 mS<br>400 mS<br>500 mS |
| **Autorange Delay:** | See Timeout Delays above. | |
| **Filter:** | Selectable 3-Pole active filter. Filter response is ≥35 dB down at 50 Hz ( ≥37 dB down at 60 Hz), attenuating 18 dB per octave above 60Hz to –60 dB or greater. | |

| DC FUNCTION | |
|---|---|
| **Ranges:** | 0.1, 1, 10, 100, 1 KV. |
| **Resolution:** | 0.001% of Range in 5-1/2 digit mode (1 μV on 0.1V Range).<br>0.01% of Range in 4-1/2 digit mode (10 μV on 0.1V Range). |
| **Maximum Input Voltage:** | ± 1000V DC or peak AC. |
| **Accuracy, Short Term, 5-1/2 Digit Mode (after DIGITAL ZERO Command):** | 24 hrs., 23°C ± 1°C<br>± (0.007% Rdg + 3 digits). |
| **Accuracy, 6 months, 23°C ± 5°C, 5-1/2 Digit Mode (after DIGITAL ZERO Command):** | 1V Range:<br>± (0.01% Rdg + 6 digits)<br>Other Ranges:<br>± (0.02% Rdg + 6 digits) |
| **Temperature Coefficient, 5-1/2 Digit Mode (after DIGITAL ZERO Command at new temperature):** | ± (0.0003% Rdg + 1 digit)/°C |
| **Input Resistance:** | 0.1, 1, 10V Ranges:<br>≥ 1000 Megohms<br>100, 1 KV Ranges:<br>10 Megohms |

* See p. 1-5 for 4½ Digit Mode Specifications

Table 1.2 - Specifications continued

| DC FUNCTION continued | |
|---|---|
| **Input Bias Current (at time of calibration):** | ≤ 50 pa at 23°C ± 1°C |
| **Input Bias Current T.C.:** | ≤ 10 pa/°C |
| **Normal Mode Rejection Ratio:** | |
| Unfiltered | 60 dB at 60 Hz (50 Hz on 50 Hz instruments). |
| Filtered | 95 dB at 60 Hz<br>90 dB at 50 Hz on 50 Hz instruments. |
| **Common Mode Rejection Ratio with up to 1 KΩ in either lead:** | 140 dB at DC<br>120 dB at 60 Hz<br>(50 Hz on 50 Hz instruments). |
| **Readout Noise:** | 0.1V Range:<br>≤ 4 digits p-p<br>Other Ranges:<br>≤ 3 digits p-p. |
| **Settling Time with up to 10 KΩ Source Resistance:** (unfiltered) | 0.1V Range:<br>10 ms to within 10 digits of final value.<br>1V, 10V Ranges:<br>5 ms to within 10 digits of final value.<br>100V, 1 KV Ranges:<br>10 ms to within 20 digits of final value. |
| **Settling Time with up to 10 KΩ Source Resistance:** (filtered) | 470 ms to within 10 digits of final value. |

| OHMS FUNCTION | |
|---|---|
| **Ranges:** | 0.1, 1, 10, 100, 1000 and 10,000 KΩ |
| **Measurement Scheme:** | Modified 4-Wire. |
| **Voltage Across Unknown (Approx.):** | −1V at F.S.<br>−2V at 100% overrange. |
| **Open Circuit Voltage:** | −6V DC maximum. |

| OHMS FUNCTION continued | | |
|---|---|---|
| **Current Through Unknown (Approx.):** | Range | Current |
| | .1 KΩ | 10 ma |
| | 1 KΩ | 1 ma |
| | 10 KΩ | 100 μa |
| | 100 KΩ | 10μa |
| | 1000 KΩ | 1μa |
| | 10,000 KΩ | 100 na |
| **Resolution:** | 0.001% of Range in 5-1/2 digit mode (1 milliohm in .1 KΩ Range).<br>0.01% of Range in 4-1/2 digit mode (10 milliohms in .1 KΩ Range). | |
| **Accuracy, Short Term, 5-1/2 Digit Mode (after DIGITAL ZERO Command):** | 24 hrs., 23°C ± 1°C<br>± (0.03% Rdg + 5 digits). | |
| **Accuracy, 6 months, 23°C ± 5°C, 5-1/2 Digit Mode (after DIGITAL ZERO Command):** | ± (0.1% Rdg + 10 digits). | |
| **Temperature Coefficient, 5-1/2 Digit Mode (after DIGITAL ZERO Command at new Temperature):** | .1 KΩ - 1000 KΩ Ranges:<br>± (0.01% Rdg + 2 digits)/°C.<br>10,000 KΩ Range:<br>± (0.015% Rdg + 2 digits)/°C. | |
| **Voltage Protection:** (without damage) | ± 375 VDC or peak AC. | |
| **Settling Time:** (Unfiltered) | 0.1 KΩ - 100 KΩ Range:<br>30 ms to within 10 digits of final value.<br>1000 KΩ Range:<br>40 ms to within 10 digits of final value.<br>10,000 KΩ Range:<br>300 ms to within 10 digits of final value. | |
| **Settling Time:** (Filtered) | 500 ms to within 10 digits of final value. | |

Table 1.2 - Specifications continued

| TRUE RMS AC FUNCTION | |
|---|---|
| **Ranges:** | 1, 10, 100, 1 KV. |
| **Maximum Input Voltage:** | 1100V peak (750V RMS sinewave). |
| **Resolution:** | .001% of Range in 5-1/2 Digit Mode (10 μV in 1V Range).<br>.01% of Range in 4-1/2 Digit Mode (100 μV in 1V Range). |
| **Accuracy, Short Term, 5-1/2 Digit Mode Sinewave Input:**<br>.1% F.S. ≤ Vin ≤ 200% F.S.<br>Frequency x Vin = $2 \times 10^7$V - Hz | 24 hrs., 23°C ± 1°C.<br>45 Hz - 10 KHz ± (0.3% Rdg + 80 digits).<br>10 KHz - 20 KHz: ± (0.5% Rdg + 100 digits). |
| **Accuracy, 6 months, 23°C ± 5°C, 5-1/2 Digit Mode Sinewave Input:**<br>.1% F.S. ≤ Vin ≤ 200% F.S.<br>Frequency x Vin= $2 \times 10^7$V - Hz | 45 Hz - 10 KHz: ± (0.5% Rdg + 100 digits).<br>10 KHz - 20 KHz: ± (0.75% Rdg + 150 digits). |
| **Temperature Coefficient:** | ± (0.02% Rdg + 20 digits)/°C. |
| **Crest Factor:** | 4:1 at Full Scale<br>$4\sqrt{\frac{\text{Range}}{\text{Input}}}$ at lower input levels. |
| **Input Impedance:** | 1 MΩ in series with .22 μF, shunted by less than 100 pF. |
| **Settling Time (Zero - F.S. or F.S. -10% F.S.):**<br>Unfiltered<br>Filtered | <br>250 ms to within 100 digits of final value.<br>350 ms to within 100 digits of final value. |

| 4-1/2 DIGIT MODE | |
|---|---|
| **Functions and Ranges:** | All Functions and Ranges. |
| **Selection:** | May be selected via front panel keyboard (RESOL Key) or GPIB command. |
| **Display:** | 4 full decades plus overrange digit. |
| **Read Rate:**<br>**(Internal Trigger):**<br><br><br>**(External or GPIB Trigger):** | <br>40 readings/sec (60 Hz instrument)<br>33 readings/sec (50 Hz instrument)<br>20 readings/sec (60 Hz instrument)<br>18 readings/sec (50 Hz instrument) |
| **Accuracy (same conditions as 5-1/2 digit mode):** | "X" % Rdg + "Y" digits where: "X" is the percentage error specified for 5-1/2 digit operation, or ± .01%, whichever is greater. "Y" is equal to the number of digits specified for 5-1/2 digit operation divided by 10, or ± 5 digits, whichever is greater. |
| **Normal Mode Rejection Ratio:** | Same as for 5-1/2 digit operation. |

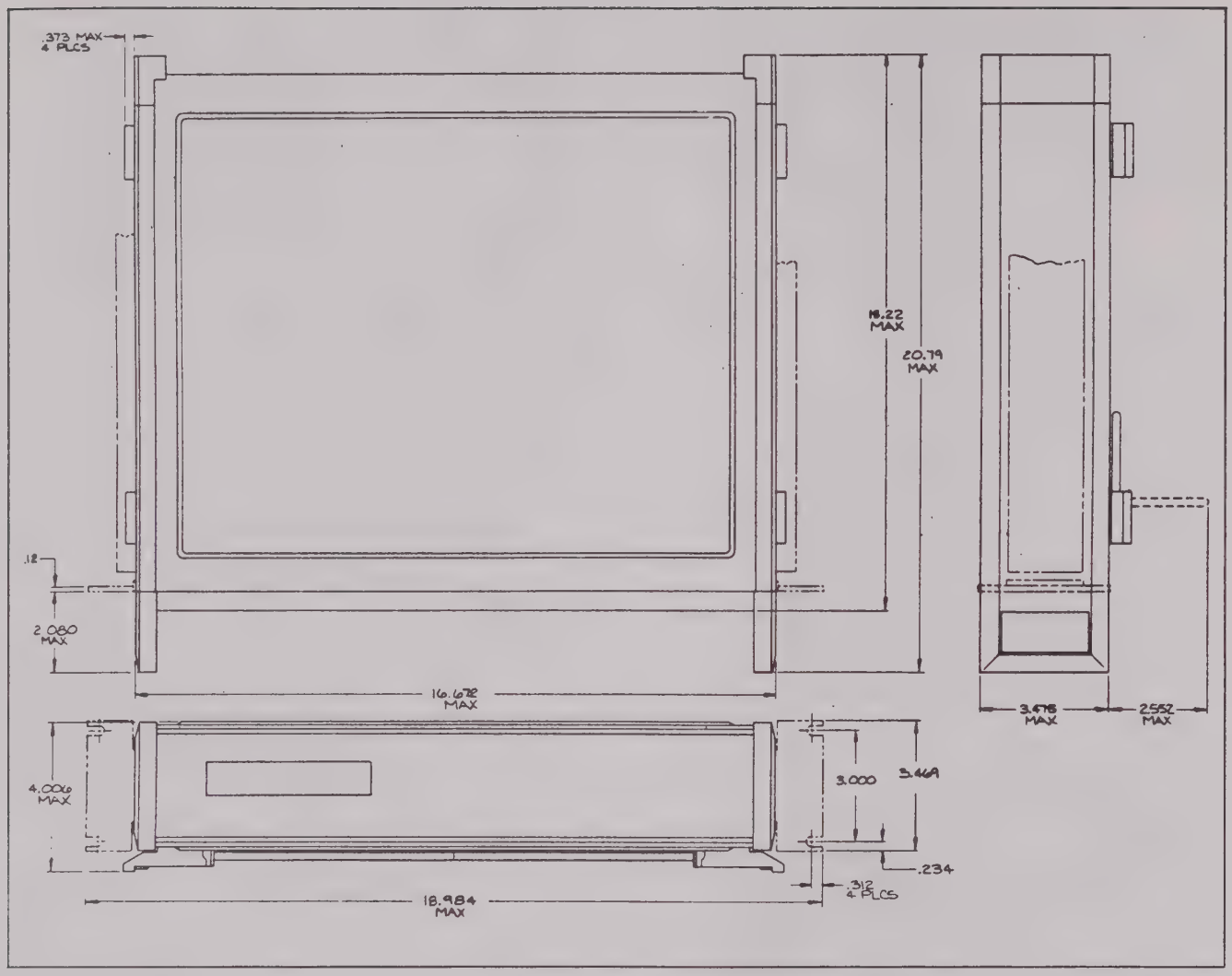



*Figure 1.2 - Dimensional Outline*

# SECTION 2 INSTALLATION

## 2.1 PURPOSE

2.1.1 This section describes the instrument installation for bench or rack mounting and optional package installation as may be required.

## 2.2 DMM UNPACKING AND INSPECTION.

2.2.1 The instrument's carton and plastic-foam packaging meets the impact and drop requirements of the NSTC Test Procedures 1 and 1A. This precaution eliminates most shipping problems.

2.2.2 Prior to unpacking the instrument, examine the exterior of the shipping carton for any signs of damage (all irregularities should be noted on the shipping bill). Carefully remove the instrument from the carton's plastic-foam packaging and inspect the instrument for any signs of damage. Notify the carrier immediately if damage is apparent and a qualified personnel should check the unit for safety.

## 2.3 BENCH OPERATION.

2.3.1 Each instrument is equipped with a tilt ball or "kickstand" to elevate the front of the instrument for easy operation. The tilt ball is attached to the two forward feet at the bottom of the instrument. When used, the ball is pulled down to its vertical position.

## 2.4 EQUIPMENT-RACK INSTALLATION.

### 2.4.1 General.

2.4.1.1 The instrument can be mounted in a standard 19 inch equipment-rack with an optional "FIXED-MOUNT" installation package or an optional "SLIDE-MOUNT" installation package. The instructions for each installation are described in subsections 2.4.2 and 2.4.3, listed next.

### 2.4.2 Fixed-Mount Installation. Option 60.

2.4.2.1 The fixed-mount installation package includes a pair of handle-sub corner inserts for the non-handle installation, a pair of custom mount angle-brackets and 4 flat head 8-32 x 5/16 screws. To install the angle-brackets, refer to Figure 2.1 for an illustrated example then proceed as follows.

2.4.2.2 To remove the bench feet, bail, or top and bottom covers, unscrew the two phillips-head retaining screws from the corner-feet about 3/4 inch. To slide off the side panels remove the retaining screws and corner feet completely.

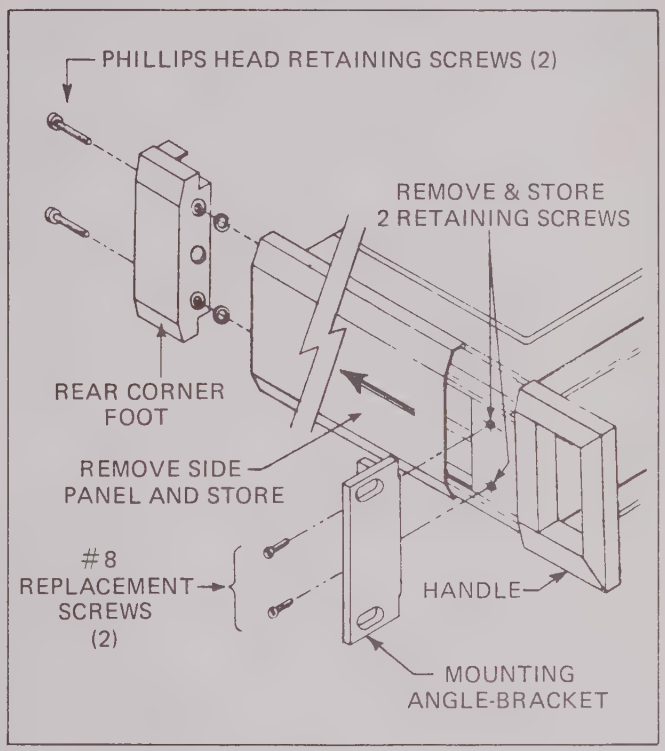



*Figure 2.1 - Fixed-mount angle-bracket detail*

2.4.2.3 Next, slide the cover 1/2 inch towards the rear panel then lift off. Remove the four bench-feet from the bottom cover by unscrewing the phillips-head retaining screw from each foot.

2.4.2.4 Remove the side panels by sliding them down the retaining track in the direction of the rear corner-feet. With the side panels off, the handle brackets retaining screws are exposed. Store the panels wherever convenient.

2.4.2.5 The two retaining screws in each handle are removed but either the handle or the handle-sub corner insert must remain in the handle position.

2.4.2.6 The angle-bracket is placed over the handle or handle-sub with the screw holes aligned over the handle holes. Insert the 2 flat-head #8-32 x 5/16 screws through both the angle-bracket and handle, then screw to the frame.

2.4.2.7 Re-install the feet at each corner of the cabinet to complete the installation.

### 2.4.3 Slide-Mount Installation. Option 67.

2.4.3.1 The slide-mount installation package includes the following hardware:

a. 2 custom-mount angle-brackets
b. 6 alignment blocks
c. 2 front slide-mount brackets
d. 2 rear slide-mount brackets
e. 2-triple-rail slide-mount assemblies
f. 12 self-anchoring #10-32 tinnerman nuts
g. 8 Phillips pan-head screws#10-32 x 1/2
h. 6 slotted #8-32 x 3/8 pan-head screws with nuts, washers, and lock washers.
i. 8 phillips pan-head, self-tapping screws #8-32 x 5/16
j. 4 phillips flat-head, self-tapping screws #8-32 x 5/16
k. 4 phillips pan-head screws #10-32 x 3/4
l. 2 alignment spacers (washers) #8 x 1/16
m. 2 handle-sub corner inserts

2.4.3.2 To install the Alignment Blocks in the channels along each side of the instrument, remove the side panels from the instrument by first removing two corner-feet by extracting the two phillips-head retaining screws. This detail is shown in Figures 2.1 and 2.2.

2.4.3.3 Next slide the covers 1/2 inch toward the rear panel then lift off. Remove the four bench-feet from the bottom cover.

2.4.3.4 Remove the side panels by sliding them down the retaining track in the direction of the rear corner-feet. With the side panels off, the handle brackets retaining screws are exposed. Store the panels wherever convenient.

2.4.3.5 The 2 handle-retaining screws are removed from each handle. This permits the handles to slip freely from the instrument.

2.4.3.6 Slide 3 alignment-blocks down each channel which are exposed by the removed handles. The drawing in Fig. 2.2 presents the front-left corner of the instrument with the handle removed. The alignment-blocks will move freely along the length of the channel on each side of the instrument.

2.4.3.7 Next, the handles, or the handle-subs, are returned to the original handle position and the custom-mount angle bracket is placed over the handle with the screw holes

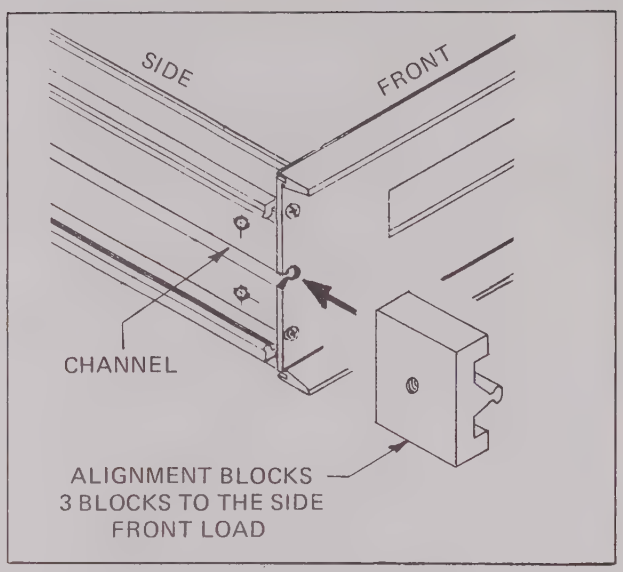



*Figure 2.2 - Loading the alignment blocks*

aligned over the handle holes. Insert 2 phillips flat-head 8-32 x 5/16 screws through both the angle-bracket and the handle, then secure to the frame. The installation of the custom mount angle-bracket completes the instrument preparation.

2.4.3.8 The following paragraph describes the preparation of the triple-rail slide-mount assembly for installation inside the equipment rack. The hole alignment on the slide-mount is an important consideration during installation, therefore physically extend and retract the slide-mount. An extended view of the slide-mount with the rear mounting bracket attached is shown in Fig. 2.3. As the slide-mount is extended and retracted, it should be noted that all holes on the instrument-rail and the rack-rail are accessible either directly or through the enlarged holes in the center-rail.

2.4.3.9 Preparing the triple-rail slide-mount for rack installation requires the following assembly:

a. Place the front slide-mount bracket, (with one mounting slot) with nut-fastening slots down, on the bench.

b. Position the front end (slide-out end) of the slide-mount over and parallel to the bracket, with the rack-rail resting within the bracket, approximately 3/4 inch from the front edge of the bracket.

c. Adjust the rails to align the rack-rail and the front-bracket holes, then place a slotted pan-head #8-32 x 3/8 screw through the holes. Attach the matching washer, lock-washer and nut to the screw and secure firmly, while maintaining the 3/4 inch dimension to the front of the bracket. Refer to Fig. 2.3 for illustrations that detail the slide-mount and bracket assembly.

d. Position the rear bracket on the opposite end of the slide-mount in the same manner as the front bracket. Adjust the rails to align the holes and place two #8-32- 3/8 screws through the holes securing the slide-mount loosely to the rear bracket with washers, lock-washer and nut.

e. Slide two self-anchoring #10-32 tinnerman nuts onto each front and rear mounting-bracket nut-fastening slots.

f. Complete the second slide-mount and bracket assembly in the same manner.

2.4.3.10 The following equipment-rack assembly instructions may require the assistance of another person. The slide-mount assembly is positioned in the designated area of the equipment rack and the installation sequence follows: NOTE: If the rack flange is tapped for #10-32 screws, drill out with a 1/4 inch diameter drill bit two places for each bracket.

a. Hold the front bracketted-end (with tinnerman nuts) of the slide-mount behind the rack flange, while the second person holds the rear-bracket end.

b. Secure the front bracket to the rack flange with two #10-32 x 1/2 screws. Seat the bracket firmly against the rack flange before tightening the screws.

c. Install the second bracket-slide-mount assembly on the rack in the same manner as the first, then set the front dimension between the slide-mounts at 16-5/8 inches.

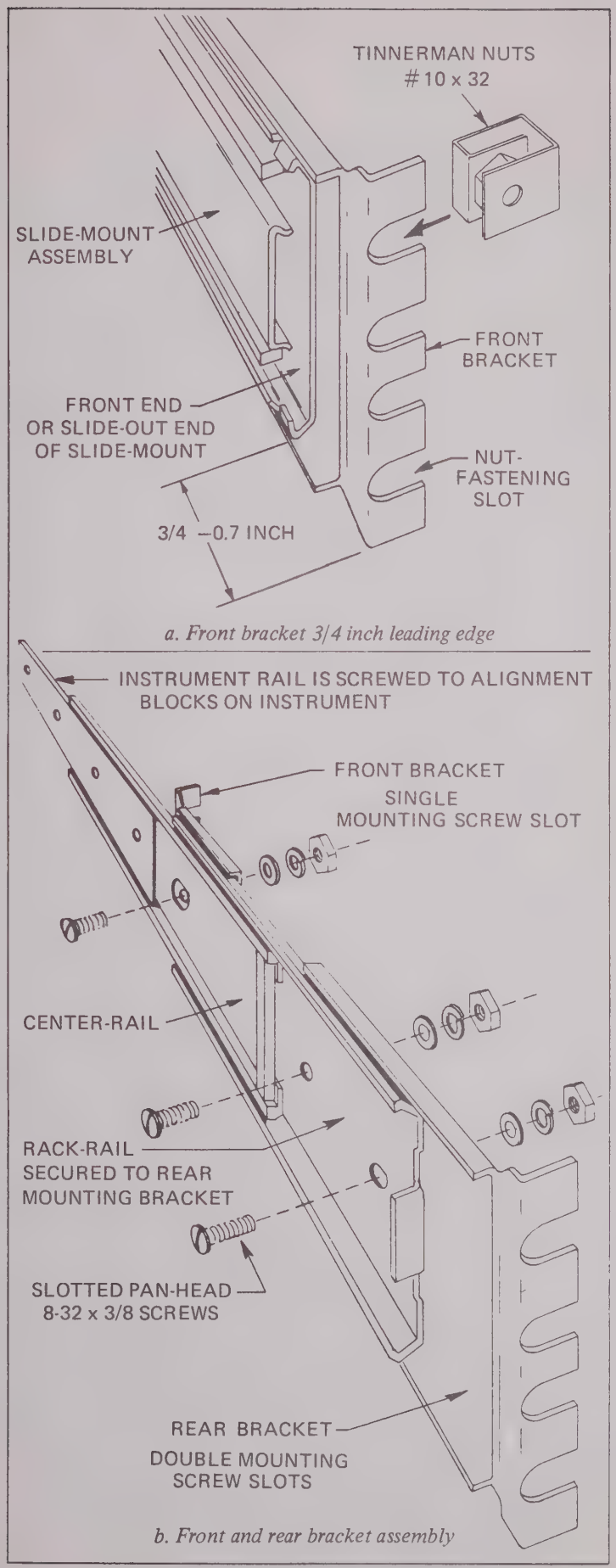

TINNERMAN NUTS
#10 x 32
SLIDE-MOUNT ASSEMBLY
FRONT BRACKET
FRONT END OR SLIDE-OUT END OF SLIDE-MOUNT
NUT-FASTENING SLOT
3/4 –0.7 INCH
a. Front bracket 3/4 inch leading edge
INSTRUMENT RAIL IS SCREWED TO ALIGNMENT BLOCKS ON INSTRUMENT
FRONT BRACKET SINGLE MOUNTING SCREW SLOT
CENTER-RAIL
RACK-RAIL SECURED TO REAR MOUNTING BRACKET
SLOTTED PAN-HEAD 8-32 x 3/8 SCREWS
REAR BRACKET DOUBLE MOUNTING SCREW SLOTS
b. Front and rear bracket assembly

*Figure 2.3 - Slide-mount and bracket assembly*

d. Extend the length of the rear mounting bracket until the bracket seats behind the rack flange. Tighten the rear-bracket assembly screws.

e. The distance between the slide-mounts at the rear bracket position must be 16-5/8 inches. If a filler-plate is required to secure the slide-mount at 16-5/8 inches employ the dimensions supplied in Fig. 2.4 for calculations.

f. Secure the rear bracket (with tinnerman nuts) to the rack flange (or filler-plate) with two #10-32 x 1/2 screws in each bracket.

g. The triple-rail slide-mounts should move freely to the maximum extended position If not, clear any obstacle before installing the instrument.

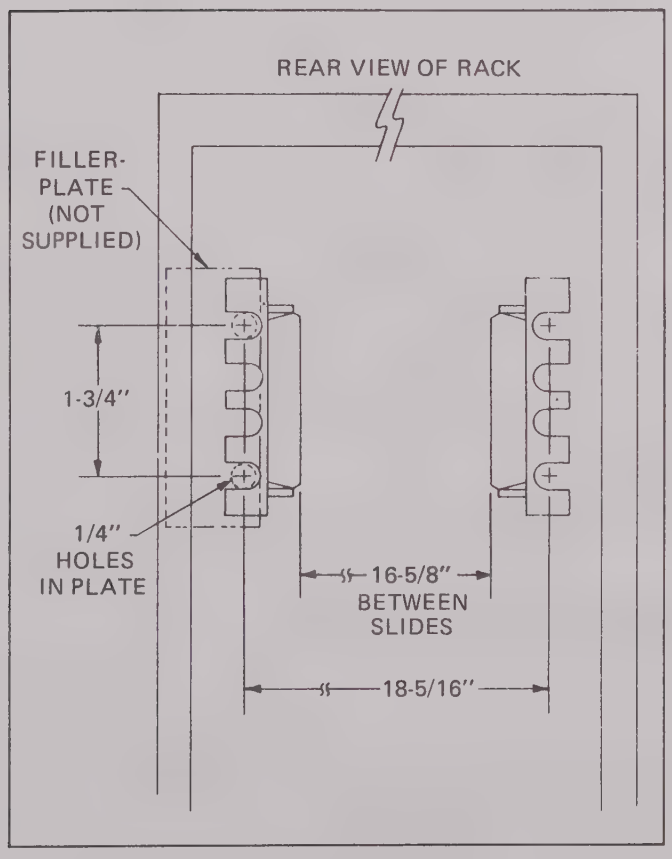



*Figure 2.4 - Rear end slide-mount rack dimensions*

2.4.3.11 The following procedure which describes the instrument installation to the side-mount implies that another person will assist.

a. Pull the rails to the maximum extended length. Insert a #8-32 x 5/16 Phillips pan-head self-tapping screw inward through the first mounting hole in each instrument rail. On the other side of the instrument rail, place an alignment spacer on the same screw.

b. Position the instrument between rails so that first screw-hole immediately behind the handle on each side, line up with the screws held by the rails. Keeping the alignment spacer between the rail and instrument seat the self-tapping screws to a pull-up position. The unit and slide-mount assembly are illustrated in Fig. 2.5.

c. Using the first mounting screw as a pivot, align the instrument with the rails and slide the front alignment-block behind the second hole on the rail. When hole alignment is obtained, screw in another #8-32 x 5/16 self-tapping screw.

d. Repeat this procedure for the remaining alignment-blocks. It is necessary to slide the rails to and fro until an access hole is located in the center-rail which aligns the instrument rail hole with the alignment-block hole.

e. Firmly seat all the self-tapping screws through the instrument rails. The instrument should slide freely on the rail.

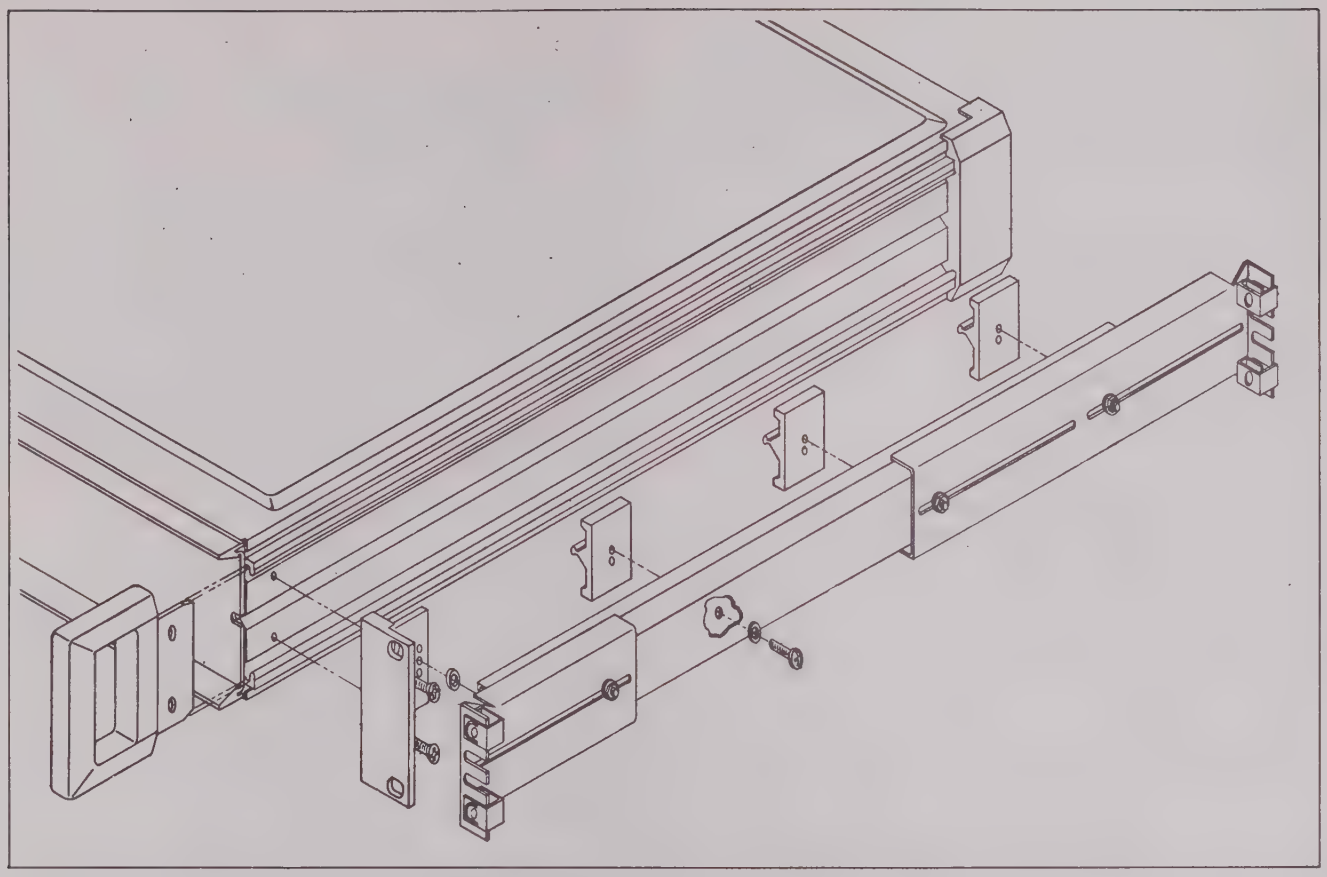


*Figure 2.5 - Slide-mount and Instrument Assembly*

2.4.3.12 Locking the instrument into the normal operating position on the rack requires the following assembly:

a. Slide two #10-32 self-anchoring tinnerman nuts on the rack flange (each side) inline with the slots in the angle-bracket. If the rack-flange is tapped for #10-32 screws, omit the tinnerman nuts.

b. Slide the instrument fully into the rack until the angle-bracket strikes the slide-mount bracket screws. Secure in place with 4 Phillips pan-head #10-32 x 3/4 screws. The installation is complete.

## 2.5 AC POWER CONNECTIONS.

2.5.1 Standard units operate on either 100, 120, 220 or 240 volts, 60 Hz (50 to 400 Hz available). Power consumption is less than 25 watts. Operation on any one of the four line voltages is selected by the placement of a small printed circuit card (P2), located in J2 receptacle on the main PCB. Selection of a specific line voltage is accomplished as follows:

2.5.1.1 Disconnect the power cord from the AC power source.

**WARNING**

Removal of covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while unit is connected to AC power source.

2.5.1.2 Remove the instrument top cover by removing each corner foot as described in paragraph 2.4.2.2. Next, slide the top cover toward the rear panel approximately half inch, then lift the cover from the frame.

2.5.1.3 Remove the two screws holding the plastic protective cover over the voltage selector.

2.5.1.4 Remove the voltage card-selector P2 from the J2 receptacle, then reinsert it permitting the desired line voltage number to be visible through the small view window on the rear panel of the instrument.

2.5.1.5 To reassemble the instrument, place the top cover on the frame with the side flanges fitting correctly in the frame grooves and the front edge of the cover approximately one inch from the front panel. When correctly seated on the frame, slide the cover forward until the front edge slides under the front panel. Replace the rear corner feet, insuring that the top cover rear corners slide under the paw on each rear foot.

## 2.6 GROUNDING REQUIREMENTS.

2.6.1 The front panel and cabinet of the instrument are grounded in accordance with MIL-T-28800B to protect the user from possible injury due to shorted circuits. The three conductor AC power cable (P/N 600620) supplied with the instrument maintains a low impedance path to ground when connected to a three wire single phase AC receptacle. This device or other devices connected to or in proximity to this instrument must maintain the third-wire earth ground intact as stated in current regulations.

## 2.7 SHIPPING CONTAINER REQUIREMENTS.

2.7.1 When shipping the instrument, the original shipping carton with the plastic packaging forms and plastic dust cover provide the necessary protection during trans-shipments. This carton should be preserved if possible.

2.7.2 When the original shipping carton is not available, reconstruct the packaging using a can of spray plastic foam to surround the plastic-wrapped unit in the carton.

## 2.8 INPUT-OUTPUT CABLES.

2.8.1 The input terminals used on the front and rear panels are standard banana jacks. The spacing among the banana jacks permits a molded dual banana plug to be connected directly between binding posts. The dual banana plug cables are available under Racal-Dana part number 402190.

2.8.2 The BNC connectors mounted on the rear panel are standard items common to systems installations, therefore not supplied by Racal-Dana.

2.8.3 The interface connector, common to IEEE-488-78 and Racal-Dana's GPIB; mounted on the rear panel accepts the standard IEEE-488 connector, Racal-Dana's part number 406845, GPIB cable, 1 meter (3.28 ft.); 406844, GPIB cable, 2 meters (6.56 ft.); 406846, GPIB cable, 4 meters (13.12 ft.).

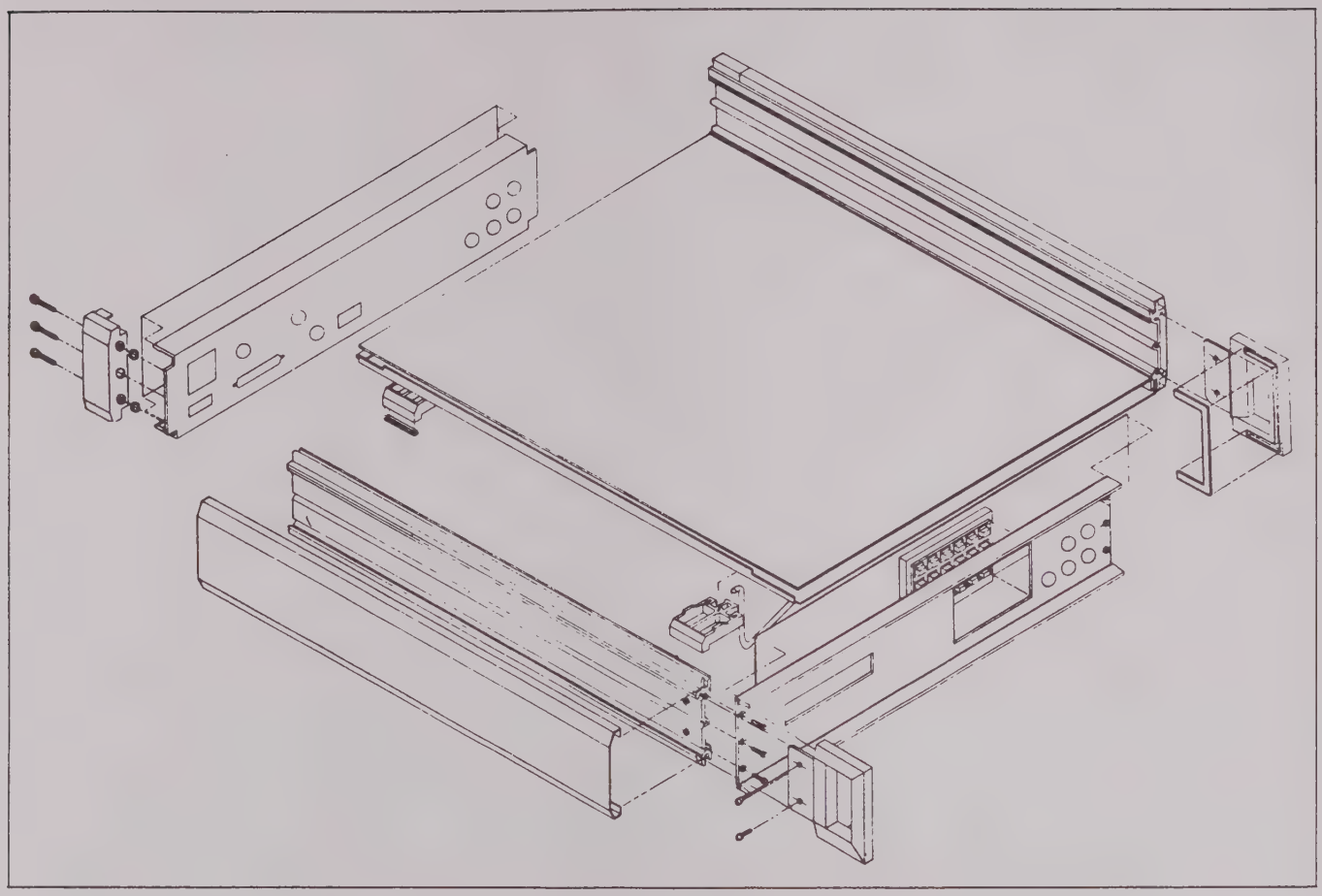


*Figure 2.6 - Cabinet Exploded View*

# SECTION 3 OPERATION

## 3.1 INTRODUCTION.

3.1.1 This section contains operating information for the DMM. The information contains illustrations of all front and rear panel controls, indicators and connectors along with tabular listing of the function and purpose for each. Operating instructions for manual or bench operation are presented in two ways; a description of each operating feature followed where necessary, with a step-by-step operating example. Some operating features or functions are simple one or two step operations and thus no operating examples are included.

3.1.2 Remote operation via the IEEE-STD-488-1978 General Purpose Interface Bus is one of the principal features of the DMM. This section presents bus address selection information and a tabular listing of the device-dependent messages used to program the instrument. Also included is a GPIB program, measurement and data transfer example.

## 3.2 OPERATION.

3.2.1 Before operating the instrument, it is strongly recommended that the operator read this entire section in order to avoid damage to the unit. After reading the operating instructions, refer to the installation section, then check the position of the line voltage selector through the viewing window on the rear panel.

**CAUTION**

This instrument may be damaged if operated on line voltage other than that called for by the line voltage selection card, P2.

**WARNING**

Removal of covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while unit is connected to AC power source.

3.2.2 After ensuring that the line voltage selector is in the proper position and the cover on the instrument replaced, connect the power cord to the AC outlet and turn the DMM on by depressing the switch. Verify that the DMM displays "5004" during the first few seconds after applying power and that the DMM annunciators for "⎓V", "AUTO" and "Range" are ON within a few seconds after applying power.

## 3.3 CONTROLS AND INDICATORS.

3.3.1 The front panel keyboard switches execute all the functions and modes of operation when the DMM local function is selected.

3.3.2 The panel designators, keyboard switches (refer to as key) and locations for all controls, indicators, and connectors are illustrated on Figure 3.1 and Figure 3.2. The description for each are itemized in Table 3.1 and Table 3.2.

## 3.4 BASIC MEASUREMENTS.

### 3.4.1 Digital Zero Command.

3.4.1.1 This procedure should be employed after turn-on and at other selected intervals to verify the DMM's zero accuracy in the DC Function.

3.4.1.2 To check the DMM's zero accuracy, short the HI-LO INPUT terminals together and verify a display read-out of zero ± 3 digits in each DC range. If the reading exceeds this limit, in any range, perform a digital zero command as described below:

a) Short the HI-LO INPUT terminals.

b) Select the DC function, .1 range.

c) Depress and hold the .1 Range Key until the display reads "CAL 0", verifying that the zero command was enabled. Release the .1 range key.

d) REMOTE OPERATION: The GPIB command K2, the digital zero command program instruction is described in paragraph 3.5.18.

### 3.4.2 Range Control.

3.4.2.1 Upon initialization, the DMM goes to its home state; autorange and continuous readings. With a signal applied to the input HI-LO terminals, the autorange will set the range to match whatever signal the DMM sees at the input terminals. For example, if a 6 volt battery is connected to the input terminals and the DMM is initialized by power turn-on, the DMM goes through the auto-test routine and the autorange will select the 10 volt range.

3.4.2.2 To manually disable autorange, depress one of the range keys. This action extinguishes the autorange annunciator and the DMM will now respond to the selected range.

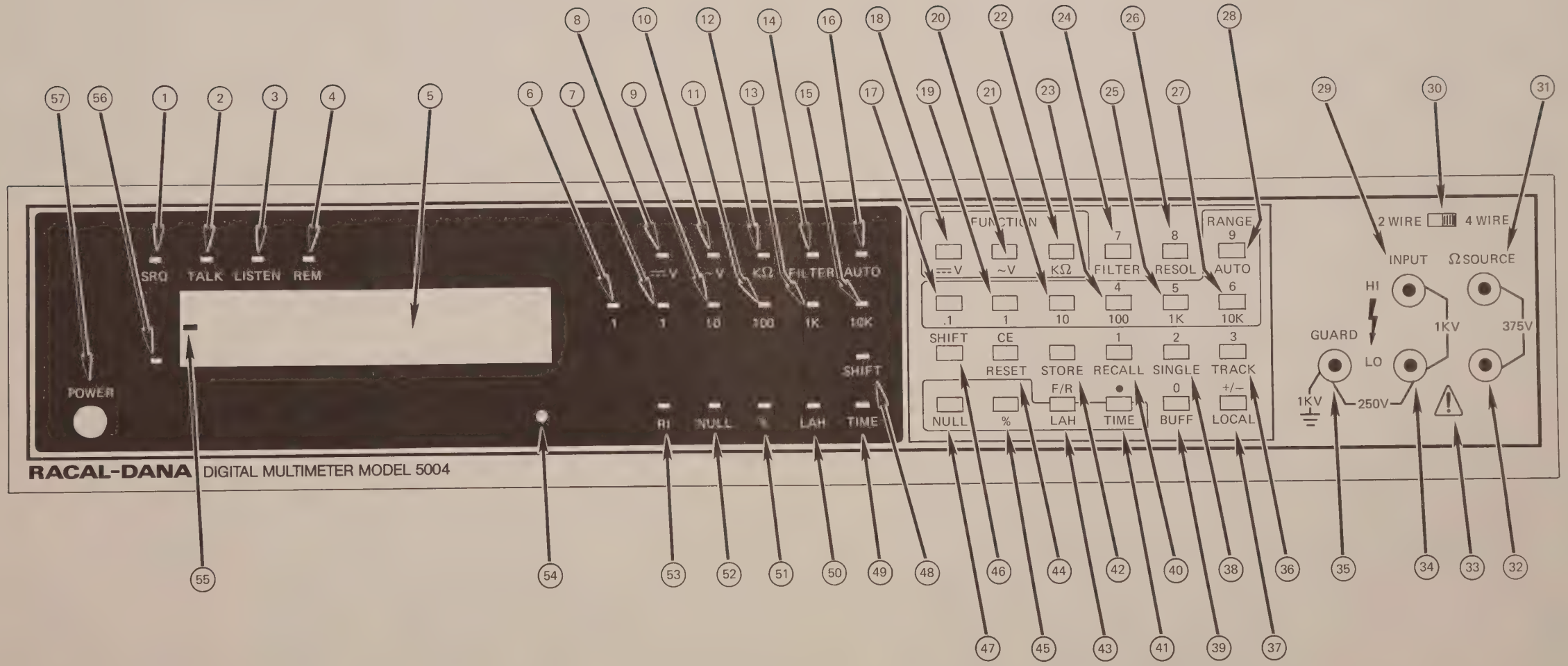



*Figure 3.1 - Front Panel Location Guide*

**Table 3.1 - Front Panel Controls, Connectors and LEDs**

| Reference | Designator/Label | Functions |
|---|---|---|
| (1) | SRQ LED ANNUNCIATOR | ON: Indicates that the DMM is transmitting a service request (interrupt) to the controller in systems operation. |
| (2) | TALK LED ANNUNCIATOR | ON: Indicates that the DMM is programmed by the controller to function as a talker on the GPIB. |
| (3) | LISTEN LED ANNUNCIATOR | ON: Indicates that the DMM is programmed by the controller to function as a listener on the GPIB. |
| (4) | REM LED ANNUNCIATOR | ON: Indicates that the controller has placed the instrument in the remote operation mode. |
| (5) | DISPLAY LEDs 7-SEGMENT | These LEDs display the value of the input signal with appropriate decimal point. They are also used to display constants and function symbols. |
| (6) ↓ (16) | MATCHING DESIGNATORS ANNUNCIATOR LEDs | This group of designators match the designators for Function, Range, Filter and Auto-Ranging. The illuminated LED agrees with the key selected. |
| (17) | □ .1 RANGE SELECTOR KEY | Selects .1 VDC or .1 KΩ ranges. ".1" annunciators illuminate. |
| (18) | □ ⎓V FUNCTION SELECTOR KEY | Selects DC Function, enables autoranging and continuous readings (internal trigger). ⎓ V annunciator is illuminated. |
| (19) | □ 1 RANGE SELECTOR KEY | Selects 1 VDC, 1 VAC or 1 KΩ ranges. "1" annunciator is illuminated. |
| (20) | □ ~ V FUNCTION SELECTOR KEY | Selects True RMS AC Function, enables autoranging and continuous readings (internal trigger). ~ V annunciator is illuminated. |
| (21) | □ 10 RANGE SELECTOR KEY | Selects 10 VDC, 10 VAC or 10 KΩ ranges. "10" annunciator is illuminated. |
| (22) | □ KΩ FUNCTION SELECTOR KEY | Selects Resistance Function, enables auto-ranging and continuous readings (internal trigger). KΩ annunciator is illuminated. |
| (23) | □ 100 RANGE SELECTOR KEY | Selects 100 VDC, 100 VAC or 100 KΩ ranges. "100" annunciator is illuminated. |
| (24) | □ FILTER FILTER SELECTOR KEY | Toggles the 3-pole active filter. FILTER annunciator is illuminated when filter is selected. |
| (25) | □ 1K RANGE SELECTOR KEY | Selects 1 KVDC, 1 KVAC or 1000 KΩ ranges. "1K" annunciator is illuminated. |
| (26) | □ RESOL RESOLUTION SELECTOR KEY | Selects 4-1/2 digit mode if operating in 5-1/2 digit mode; selects 5-1/2 digit mode if in 4-1/2 digit mode. |

**Table 3.1 - Front Panel Controls, Connectors and LEDs continued**

| Reference | Designator/Label | Functions |
|---|---|---|
| (27) | ☐ 10K RANGE SELECTOR KEY | Selects 10,000 KΩ range. "10K" annunciator is illuminated. |
| | | NOTE: Selection of any range key disables auto-ranging. |
| (28) | AUTO AUTO-RANGING SELECTOR KEY | Toggles AUTO ranging mode. If AUTO ranging is selected, depressing this key or a range key returns to manual range control. AUTO annunciator is illuminated when in auto-ranging mode. |
| (29) | INPUT HI BANANA JACK | + Signal Input (J104). |
| (30) | 2-WIRE/4-WIRE SWITCH | Front panel mounted slide switch that connects Ω SOURCE terminals to INPUT terminals for two wire resistance measurements when in 2-wire position. Terminals are disconnected in 4-wire position. |
| (31) | Ω SOURCE BANANA JACK | Ω CURRENT RETURN (J105). |
| (32) | Ω SOURCE BANANA JACK | Ω CURRENT SOURCE (J103). |
| (33) | ⚠ CAUTION SYMBOL | REFER TO THE MANUAL IN ORDER TO PROTECT THE INSTRUMENT AGAINST DAMAGE. |
| (34) | INPUT LO BANANA JACK | – Signal Input (J102). |
| (35) | GUARD BANANA JACK | Front Panel connector to internal guard shield (J101). |
| (36) | ☐ TRACK READ-OUT SELECTOR KEY | Causes instrument to take continuous readings at maximum read rate (internal trigger). |
| (37) | ☐ LOCAL LOCAL SELECTOR KEY | Returns control from GPIB to front panel (if not disabled from controller). Displays instrument's GPIB address while Key is held depressed. |
| (38) | ☐ SINGLE READ-OUT SELECTOR KEY | Causes instrument to go into "Hold" mode. Takes single reading each time Key is depressed. |
| (39) | ☐ BUFF DATA BUFFER SELECTOR KEY | Provides a means for recalling previous readings from the data buffer to the display. Pressing the button for more than 5 seconds will clear the data buffer. |
| (40) | ☐ RECALL RECALL SELECTOR KEY | Enables RECALL access for the constants previously stored as Null, %, LAH, and BUFF. |
| (41) | ☐ TIME TIME SELECTOR KEY | Provides a means of taking a series of measurements under control of the voltmeters built-in real-time clock. Start time, stop time and reading intervals can be selected and entered via the keyboard. TIME annunciator is illuminated when instrument is under control of Time function. |

**Table 3.1 - Front Panel Controls, Connectors and LEDs continued**

| Reference | Designator/Label | Functions |
|---|---|---|
| (42) | ☐ STORE<br>STORE ENABLER KEY | Stores number on display, last reading or numerical entry. |
| (43) | ☐ LOW-AVERAGE-HIGH<br>LAH FUNCTION SELECTOR KEY | Selects function that compares the present reading with previously determined Low (most negative) or High (most positive) readings. Stores the present reading in place of one of these if it is found to be lower or higher. Also calculates and stores the average value of a selected number of readings. The Low, Average, High or number of readings averaged can be selected for a continuous display or recalled from memory and displayed. The number of readings to be averaged can be entered prior to selection of LAH operation, and this number can be recalled from memory and displayed.<br><br>LAH annunciator is illuminated when function is enabled. |
| (44) | ☐ RESET<br>RESET KEY | Removes previously selected "Math" functions. Enables continuous readings and lights all front panel annunciators and display segments. |
| (45) | ☐ PERCENT FUNCTION<br>% SELECTOR KEY | Calculates and displays:<br>$\frac{\text{Reading-Percent Constant}}{\text{Percent Constant}} \times 100$<br>which is the percentage deviation of the input reading from a reference value called "Percent Constant" (stored reading or constant entered via keyboard). % annunciator is illuminated when % function is enabled. |
| (46) | ☐<br>SHIFT KEY | Allows access to numerical entry, Rear Input and Clear Entry keys. SHIFT annunciator indicates whether the keyboard is in the shifted or unshifted mode. |
| (47) | ☐ NULL FUNCTION<br>NULL SELECTOR KEY | Selects Null function. When selected, the number on the display is stored as a Null constant and is subtracted from all future readings until the Null function is disabled by depressing the NULL key again. The Null constant can be either the measurement value at the time Null is selected or a value entered via the keyboard. NULL annunciator is illuminated when Null function is enabled. |

**Table 3.1 - Front Panel Controls, Connectors and LEDs continued**

| Reference | Designator/Label | Functions |
|---|---|---|
| | DOUBLE KEY-STROKE ENTRY<br>The following keys are SHIFTED functions | |
| | SHIFT + CE | The "Clear Entry" key clears numbers entered into display and returns the instrument to its previous state. |
| | SHIFT + N | Where N = 0 to 9. Enters numbers into display in preparation for storage in memory as constants (e.g., Null Constant, Reference Value for percent deviation, etc.). Depressing these keys does not unshift keyboard. |
| | SHIFT + +/– | Reverses sign (polarity) of number entered into display. Depressing this key does not unshift keyboard. |
| | SHIFT + F/R | Toggles Front/Rear relay, K13. K13 connects either front or rear input terminals to the measurement circuits. RI annunciator is illuminated when Rear Input is selected. |
| | STORE + NULL | Stores number on display (last reading or numerical entry) as Null Constant. |
| | STORE + % | Stores number on display (last reading or numerical entry) as Percent Constant for percent deviation calculation. |
| | STORE + LAH | Stores numerical entry on display as number of readings to be averaged (c). |
| | STORE + TIME + X | Stores numerical entry on display as parameter associated with Time function, where X is:<br>1. START Time<br>2. STOP Time<br>3. Time INTERVAL<br>4. Time SUBINTERVAL<br>5. N (number of readings per INTERVAL)<br>6. PRESENT Time |
| | STORE + SHIFT + N | Where N = 0 to 9. Stores the present instrument setting into the buffer program location 0 to 9. |
| | RECALL + % | Displays Reference Value used in percent calculations. |
| | RECALL + LAH | Recalls Low (L), Average of last N readings (A), High (H), number of readings that have been averaged (n), and the number of readings to be averaged (c). The number of readings to be averaged (c) is entered via the keyboard prior to selecting LAH operation. c = 4 if no entry is made. |

**Table 3.1 - Front Panel Controls, Connectors and LEDs continued**

| Reference | Designator/Label | Functions |
|---|---|---|
| | □ RECALL □ BUFF | Recalls readings stored in buffer memory to the display. |
| | □ RECALL □ NULL | Displays value of Null constant. |
| | SHIFT □ N □ □ RECALL | Where N = 0 to 9. Recalls machine settings previously stored in program buffer and programs the instrument to these settings. |
| (48) ▼ (53) | MATCHING DESIGNATORS ANNUNCIATOR LEDS | This group of annunciator LEDs match the designators for SHIFT, TIME, LAH, %, NULL and rear input (RI). |
| (54) | CALIBRATION SWITCH | Spring loaded pushbutton switch, accessible through hole in front panel. Switch is held depressed during software calibration to enter calibration constants into Non-Volatile Memory. |
| (55) | SIGN INDICATOR | LED illuminates to display the negative sign when the display reading is negative. |
| (56) | READ-RATE INDICATOR | Front panel LED indicator that illuminates when the DMM takes a reading. |
| (57) | POWER SWITCH | Push-on, Push-off type switch on front panel. |

**Table 3.2 - Rear Panel Terminals and Control**

| Reference | Designator/Label | Functions |
|---|---|---|
| (1) | Ω SOURCE<br>BANANA JACK | Ω Current Return (J206). |
| (2) | INPUT HI<br>BANANA JACK | + Signal Input (J207). |
| (3) | SYNC OUTPUT<br>BNC CONNECTOR | Outputs negative going TTL pulses each time a reading is displayed. Used to synchronize input scanners, such as Racal-Dana 1200. |
| (4) | FUSE HOLDER | .5 Amp "Slo-Blo" (115V).<br>.25 Amp "Slo-Blo" (220V). |
| (5) | AC POWER PLUG | Accepts Racal-Dana AC cord 600620., and European standard cord P/N 600858. |
| (6) | ADDRESS SWITCH | GPIB ADDRESS SWITCH. DMM bus number selector. |
| (7) | GPIB CONNECTOR | GPIB port (J201). |
| (8) | EXTERNAL TRIGGER<br>BNC CONNECTOR | A negative going TTL level pulse applied to this connector initiates a measurement cycle when in " Hold " mode. |
| (9) | LINE VOLTAGE<br>SELECTOR WINDOW | The selected AC voltage viewing window. |
| (10) | GUARD<br>BANANA JACK | Rear panel connector to internal guard shield (J205) connected internally to front panel guard connector (J101). |
| (11) | INPUT-LO<br>BANANA JACK | –Signal Input (J204). |
| (12) | Ω SOURCE<br>BANANA JACK | Ω Current Source (J203). |

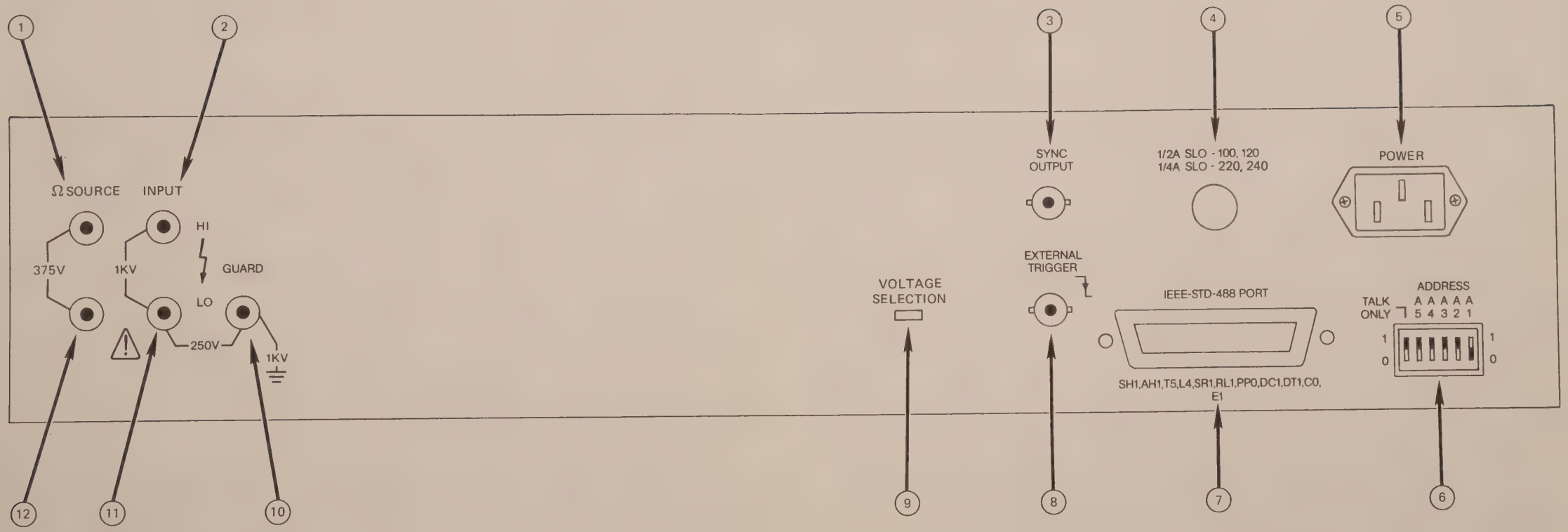



*Figure 3.2 - Rear Panel*

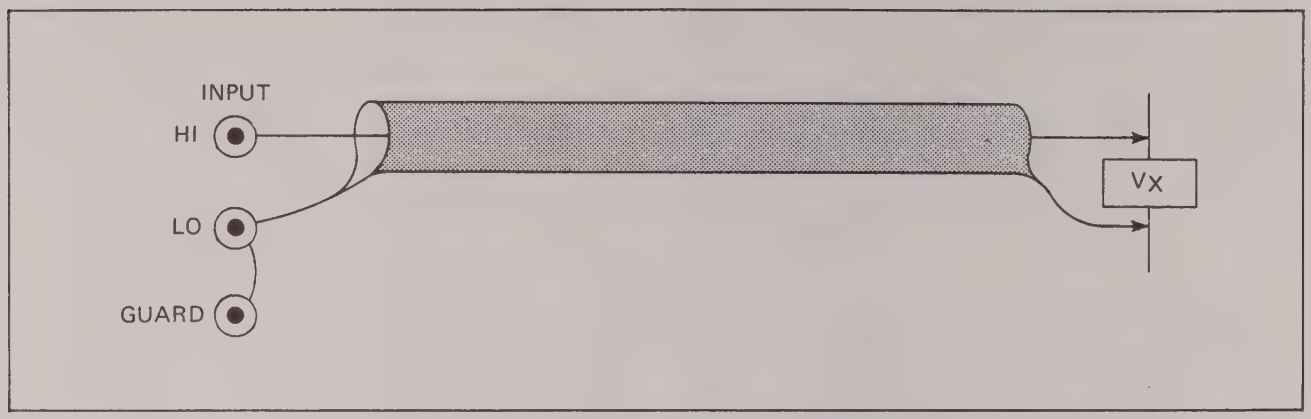



*Figure 3.3 - DC, AC Measurement Connections Using Coaxial Cable*

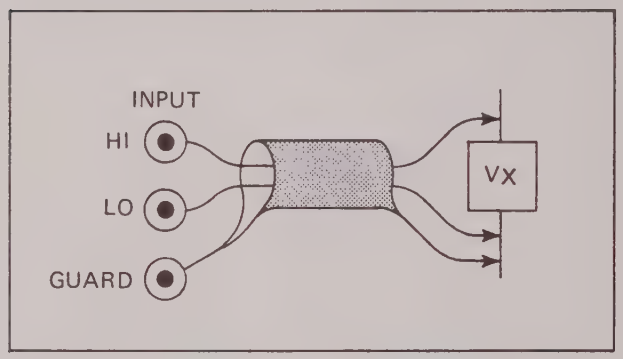



*Figure 3.4 - DC, AC Measurement Connection Using Two Conductor Shielded Cable*

### 3.4.3 DC Volts Measurements.

3.4.3.1 The basic instrument is capable of measuring DC volts in 5 ranges: 0.1V, 1V, 10V, 100V, 1000V. To measure DC voltage proceed as follows:

3.4.3.2 Complete the DMM turn-on procedure as described in paragraph 3.2.2, then check the zero accuracy of the instrument as described in paragraph 3.4.1.

3.4.3.3 Connect the DC voltage to the INPUT HI-LO terminals, refer to Figure 3.3 and Figure 3.4, and read the value from the display and range annunciators.

### 3.4.4 AC Volts Measurements.

3.4.4.1 The DMM is capable of measuring AC volts in 4 ranges: 1V, 10V, 100V, 1000V. To measure AC voltage proceed as follows:

3.4.4.2 Complete the DMM turn-on procedure as described in paragraph 3.2.2.

3.4.4.3 Select the AC volts function by pressing the AC key, then verify that the AC annunciator LED is on.

3.4.4.4 Connect the AC voltage to the INPUT HI-LO terminals, refer to Figure 3.3 and Figure 3.4, and read the value from the display and range annunciators.

### 3.4.5 Resistance Measurements.

3.4.5.1 The DMM is capable of measuring resistance values in six ranges, starting at 100 ohms full scale to 10,000,000 ohms full sclae. The correlation between the front panel keyboard and resistance selection is best described by the chart that compares range designators and resistance scales, as follows:

a) When the KΩ function is selected, the range keys carry a scaled factor of 1000 or range key "1" equals one thousand ohms full scale.

b) Range keys and resistance measurement comparison:

| Range Key | Ohms - Full Scale | |
|---|---|---|
| .1 | 100 | Ohms |
| 1 | 1000 | Ohms |
| 10 | 10,000 | Ohms |
| 100 | 100,000 | Ohms |
| 1K | 1,000,000 | Ohms |
| 10K | 10,000,000 | Ohms |

3.4.5.2 Furthermore, the operator has the option of selecting two-wire or four-wire mode of operation through the front panel switch, No. 30 on Figure 3.1. This selection is determined by the accuracy required by the User and the environment. The application and description for each system is described in the procedures that follow.

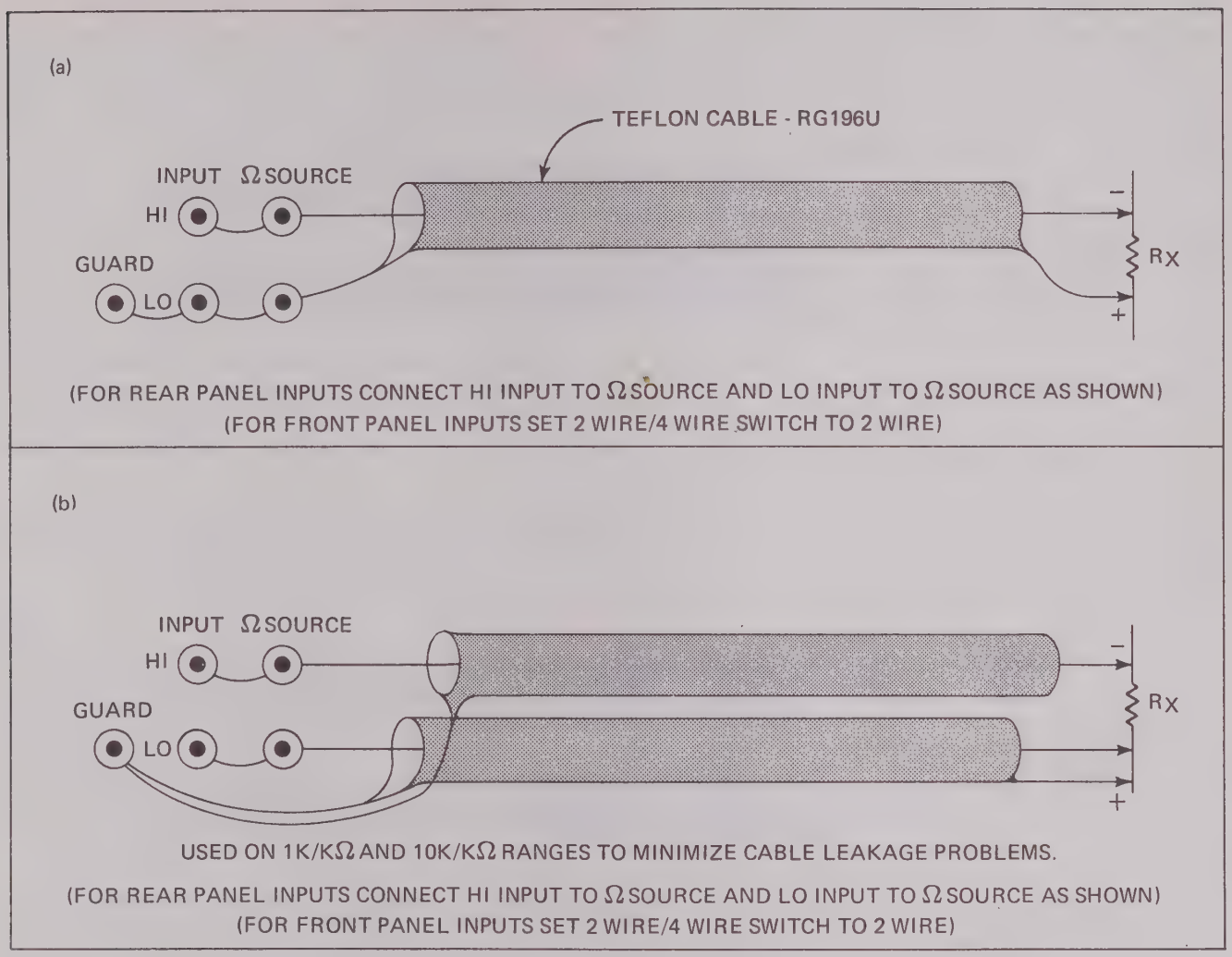

(a)
TEFLON CABLE - RG196U
INPUT ΩSOURCE
HI
GUARD
LO
Rx
(FOR REAR PANEL INPUTS CONNECT HI INPUT TO ΩSOURCE AND LO INPUT TO ΩSOURCE AS SHOWN)
(FOR FRONT PANEL INPUTS SET 2 WIRE/4 WIRE SWITCH TO 2 WIRE)
(b)
INPUT ΩSOURCE
HI
GUARD
LO
Rx
USED ON 1K/KΩ AND 10K/KΩ RANGES TO MINIMIZE CABLE LEAKAGE PROBLEMS.
(FOR REAR PANEL INPUTS CONNECT HI INPUT TO ΩSOURCE AND LO INPUT TO ΩSOURCE AS SHOWN)
(FOR FRONT PANEL INPUTS SET 2 WIRE/4 WIRE SWITCH TO 2 WIRE)

*Figure 3.5 - Two Wire Ohms Measurements*

3.4.5.3 Two-Wire measurements through the Front or Rear Panel INPUT terminals are connected as shown in Figure 3.5A and 3.5B using Teflon shielded cable as indicated. The Two-Wire/Four-Wire switch on the front panel, No. 30 on Figure 3.1, is placed in the two-wire position, this automatically connects the Ohms Source terminals to the Voltage Input (sense) terminals. When rear terminal input is used, a jumper is required between the Ohms Source terminal and the HI Input, then another jumper is required between the other Ohms Source terminal and the LO Input terminal. These connections and the GUARD connection to LO input are shown on Figure 3.5. When performing polarity sensitive resistance measurements (e.g.semiconductor junctions), note the polarity of the voltage across the Ω SOURCE terminals (upper terminal is negative with respect to lower terminal).

3.4.5.4 Accurate measurements can be obtained with the two-wire system presented, except in the .1 and 1 ranges. At low resistance levels, lead resistance between Rx and the DMM can become a significant error factor. In this instance a four wire system is recommended to minimize lead resistance errors.

3.4.5.5 When measuring resistances in the 1K/KΩ and 10K/KΩ ranges, cable leakage may cause measurement errors if the connections of Figure 3.5A are used. The amount of inaccuracy will depend on the cable insulation and environmental conditions (e.g., high relative humidity, etc). For this reason, teflon insulation is recommended to minimize cable leakage. If teflon cable is not used, then the two wire cable wiring diagram of Figure 3.5B is recommended.

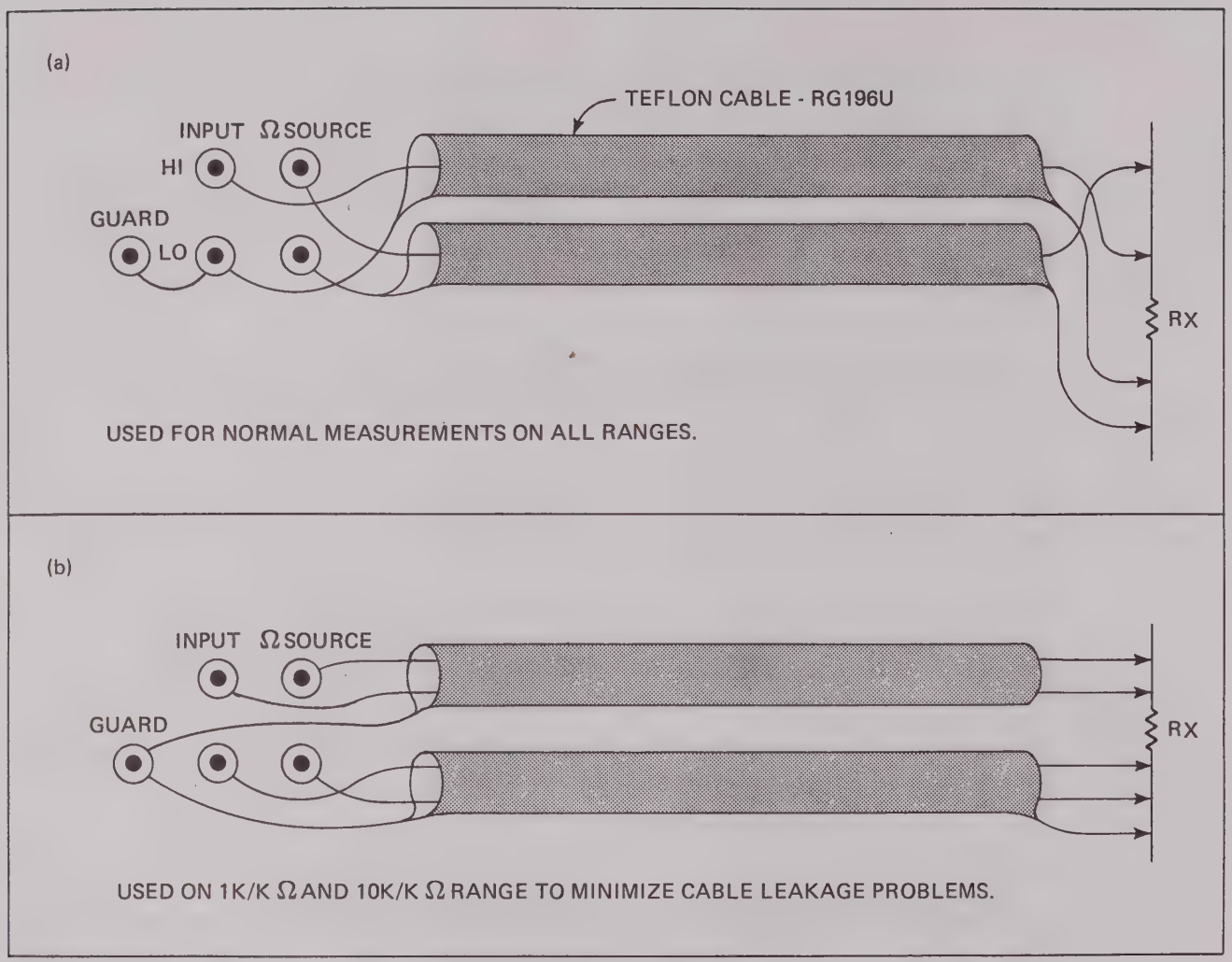



*Figure 3.6 - Four Wire Ohms Measurement*

3.4.5.6 Four Wire Measurement System is used in most systems applications, particularly where the device to be measured is at a remote location requiring interconnection by cables from several feet to hundreds of feet in length. When measuring low resistance values over long cables, most resistance problems can be resolved by the use of the four-wire measurement system.

3.4.5.7 The 2-Wire/4-Wire switch is set to 4-wire when front panel terminals are used for Four-Wire measurements. The four-wire resistance measurement diagrams are shown in Figure 3.6A and 3.6B. If teflon insulated coaxial cable is used, accurate measurements can be made on all ranges and under severe environmental conditions. Figure 3.6B shows the recommended connections when using two-conductor shielded cable. This wiring system eliminates most cable leakage problems when high resistances are measured with relatively high leakage cables.

### 3.4.6 Model 5004 Extended Software Capability (ESC) Features.

3.4.6.1 The 5004 Extended Software Capability increases the program capabilities of the DMM. The features include NULL, %, LAH, TIME, Program Buffer and Data Buffer. The application and control description were presented in Section 3.3. Additional information continues in this section.

3.4.6.2 These programs were designed to operate either separately or in various combinations. For instance, the % and LAH function can be used together to determine average

and worst-case percentage variations. In an another example, the Time Function and Data Buffer can be used together to monitor an input signal at pre-determined intervals and store the resulting readings for later recall. In general when two or more ESC features are enabled simultaneously, they will take place in the order shown in the ESC Feature Flow Chart, Figure 3.7.

3.4.6.3 When reviewing the Flow Chart, notice that the Time Function does not appear as a discrete block in this figure. The time function, if enabled, determines when a reading is permitted to take place; the reason will be seen later. A block for the Program Buffer was intentionally omitted since the program buffer affects the entire DMM's configuration, rather than each individual reading.

3.4.6.4 Keyboard operation which makes use of the STORE, RECALL, or numeric entry keys causes the DMM to abort the sequence shown in Figure 3.7, and instead responds only to the keyboard input. When the operator has finished with keyboard operations, he can return to the Flow Chart sequence by pressing the SHIFT then CE (clear entry) keys. Other keys such as Function, Range or the RESET key may be used, but possible interaction may occur with the DMM's setup in various ways (see the description for each key in Table 3.1).

### 3.4.7 STORE and RECALL Procedures.

3.4.7.1 The STORE key is used in conjunction with other keys to store readings, numerical constants and Instrument Program Settings in the DMM's memory.

3.4.7.2 The general procedure for STORING READINGS is presented next:

a) If a reading is not presently displayed, depress the SINGLE or TRACK key.

b) Press the STORE key.

c) Press the key or keys which specify the storage location. The STORE key operations of the Extended Software Capability (ESC) features are listed in Table 3.3.

**NOTE**

If any ESC features are enabled, (NULL, %, etc.) the number stored will not match the number displayed. The ESC Flow Diagram presented in Figure 3.7 can be used as an aid to understand this phenomenon because the Flow Chart indicates that the Input Buffer contains the unprocessed reading rather than the output of NULL, Percent, etc.

3.4.7.3 STORING NUMERICAL CONSTANTS is presented next:

a) Press the SHIFT key, the SHIFT annunciator LED will illuminate.

b) Press the Numerical Entry Keys as required to enter the constant. The enteries will appear on the display.

c) Press the STORE key.

d) Press one of the key sequences shown in Table 3.3, Store Key Operations.

**NOTE**

If an error is made keying the STORE procedure, press SHIFT and clear entry (CE) keys to return the DMM to its previous state.

3.4.7.4 The RECALL KEY is used in conjunction with other keys to examine data which is stored in the DMM's memory and to recall Instrument settings from the program buffer. The RECALL Key sequences in Table 3.4 show all the possible sequences, along with other details.

**NOTE**

If any error is made keying the RECALL procedure, press the SHIFT and clear entry (CE) keys to return the DMM to its previous state.

### 3.4.8 Low-Average-High Function.

3.4.8.1 The 5004 DMM provides a Low-Average-High (LAH) measurement capability. When used in this mode the instrument performs the following operations:

a) Stores the least positive (or most negative) value measured during LAH operation;

b) Stores the value of the most positive (or least negative) measurement made during LAH operation;

c) Calculates the average value of all measurements taken during the LAH average cycle;

d) Counts the number of measurements taken during the LAH average cycle.

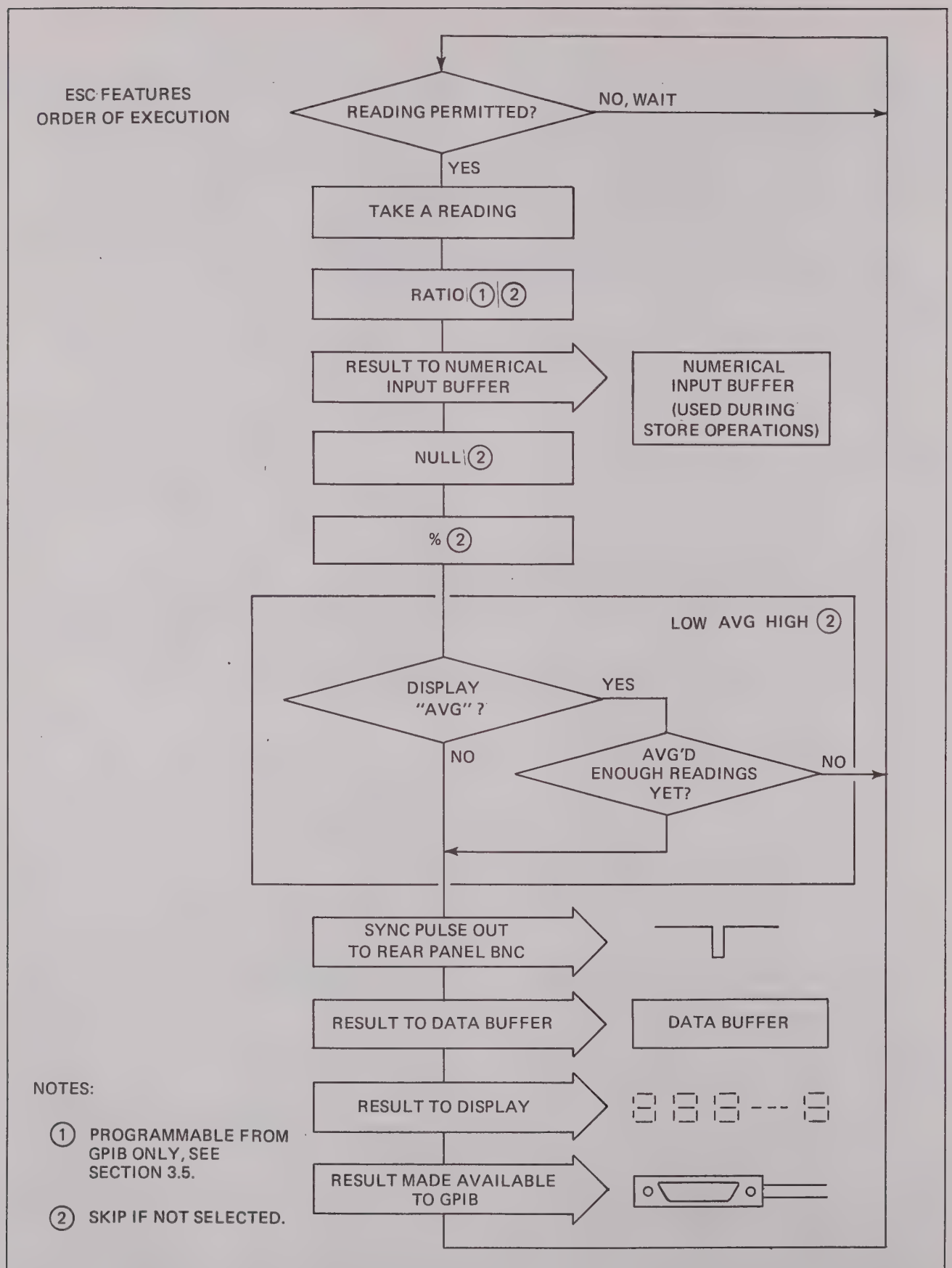



*Figure 3.7 - Extended Software Capability Feature Flow Chart*

**Table 3.3 - Store Key Operations**

| Key Sequence | Storage Location | Power-Up Value | Units | Notes | For More Info See Paragraph |
|---|---|---|---|---|---|
| STORE □ □ NULL | Null Constant | 0.00 | Volts or Kohms | Null Function should be enabled before Null constant is stored. | 3.4.10 |
| STORE □ □ % | Percent Constant | 0.00 | Volts or Kohms | | 3.4.11 |
| STORE □ □ LAH | LAH Average Cycle Count C | 4 | Dimensionless | C, the LAH Average cycle constant should be between 1 and 10,000. If C = 10,000 A and N will not periodically reset. | 3.4.8 |
| STORE □ □ TIME 1 □ | Start Time | 00.0000 | Hr. Min Sec | (1) | 3.4.9 |
| STORE □ □ TIME 2 □ | Stop Time | 99.0000 | Hr. Min Sec | (1) | |
| STORE □ □ TIME 3 □ | Interval | 00.0000 | Hr. Min Sec | (2) | |
| STORE □ □ TIME 4 □ | Subinterval | 00.0000 | Hr. Min Sec | (2) | |
| STORE □ □ TIME 5 □ | N (number) | 1 | Dimensionless | (3) | |
| STORE □ □ TIME 6 □ | Present Time | 00.0000 | Hr. Min Sec | (1) (4) | |
| STORE □ SHIFT □ 9 □ . . . . 0 □ | Program Buffer | Empty | N/A | Stores the entire DMM's present setting into the Program Buffer, and initializes the Data Buffer. | 3.4.12 |

(1) A time-of-day number which should be set between 00.0000 and 95,5959 for normal operation, or set greater than 95.5959 to place constant at infinity on time scale.

(2) An elapsed-time constant same numerical limits apply as in (1)

(3) An Integer, normally set between 1 and 99

(4) Automatically increments to track the passing of time.

**Table 3.4 - Recall Key Operations**

| Key Sequence | Recall Location | Power-Up Value | Units | Notes | For More Info See Paragraph |
|---|---|---|---|---|---|
| □ □ RECALL NULL | Null Constant | 0.00 | Volts or Kohms | | 3.4.10 |
| □ □ RECALL % | Percent Constant | 0.00 | Volts or Kohms | | 3.4.11 |
| □ □ RECALL LAH | Lowest Reading | Blank Display | Volts or Kohms | (1) | 3.4.8 |
| □ □ RECALL LAH | Average Reading | Blank Display | Volts or Kohms | (1) (2) | |
| □ □ RECALL LAH | Highest Reading | Blank Display | Volts or Kohms | (1) | |
| □ □ RECALL LAH | Number of Readings | 0 | Dimensionless | (2) | |
| □ □ RECALL LAH | Average Cycle Constant | 4 | Dimensionless | | |
| □ □ 1 RECALL TIME □ | Start Time | 00.0000 | Hr. Min Sec | | 3.4.9 |
| □ □ 2 RECALL TIME □ | Stop Time | 99.0000 | Hr. Min Sec | | |
| □ □ 3 RECALL TIME □ | Interval | 00.0000 | Hr. Min Sec | | |
| □ □ 4 RECALL TIME □ | Subinterval | 00.0000 | Hr. Min Sec | | |
| □ □ 5 RECALL TIME □ | N (number) | 1 | Dimensionless | | |
| □ □ 6 RECALL TIME □ | Present Time | 00.0000 | Hr. Min Sec | | |
| □ □ RECALL BUFF | | | Volts or Kohms | Number at right side of display during pressing of BUF key indicates buffer location #. | 3.4.12 |
| □ SHIFT □ RECALL □ 9 . . . 0 □ | | | N/A | Programs entire instrument to setting previously stored in locations 0-9. | 3.4.12 |

(1) A blank display indicates that no answer is presently available (answer is "the empty set").

(2) Automatically initialized every C readings.

3.4.8.2 The length of the LAH average cycle is determined by an operator entered number using the procedure described in paragraph 3.4.8.4. The number entered will equal the number of readings the operator wants to average in each LAH average cycle up to a maximum of 10,000. If selected for display, a new average is displayed at the end of each LAH average cycle. However, the low and high values are derived from all readings taken since the LAH function was selected.

> **NOTE**
>
> The LAH function will update the minimum and maximum readings indefinitely, but will not update the average or the number of measurements readings beyond the first 10,000 samples.

3.4.8.3 The operator may select the lowest (most negative) measurement (L), average measurement (A), highest (most positive) measurement (H), number of measurements (n), or the present reading (r) to be displayed while the LAH function is selected. The desired display selection is described in the following procedure:

a) Depress and hold the LAH key. As long as the key is depressed, the display will repeat the sequence "L, A, H, n, r" in the least significant digit location.

b) To display the most negative reading, release the LAH key while the "L" is displayed.

c) To display the average reading, release the LAH key while the "A" is displayed.

d) To display the most positive reading, release the LAH key while the "H" is displayed.

e) To display the number of measurements taken during each LAH Average cycle, release the LAH key while the "n" is displayed.

f) To display the present measurement reading, release the LAH key while the "r" is displayed.

3.4.8.4 The desired number of measurements to be averaged during each LAH average cycle is programmed prior to entering the LAH function as follows:

a) Press the SHIFT key.

b) Key in the number of measurements to be averaged (e.g., press the 5 key and then the 8 key to select 58 measurements).

c) Press the STORE key.

d) Press the LAH key. The number of measurements constant (c) will remain in memory until it is changed or until power is removed from the instrument.

e) Select the desired display by following the procedure in the preceding paragraph. If the average reading is selected for display, the display will be updated each time the selected number of measurements is completed (e.g., every 58 measurements).

f) If the operator is not interested in using the LAH function's averaging capabilities, the LAH average cycle constant need not be initialized.

3.4.8.5 The operator, when using the RECALL key has access to the data stored during LAH operation. Press the key RECALL, then LAH and a letter will appear in the least significant digit location. Upon release of the LAH key, the letter will be replaced with the following corresponding data:

a) C: Number of readings averaged each LAH average cycle, operator entered as described in 3.4.8.4.

b) L: The least positive (most negative) reading that has occurred since the LAH function was selected.

c) A: The average computed over N readings (see N below).

d) H: The most positive (least negative) reading that has occurred since the LAH function was selected.

e) N: The number of readings taken during the present LAH average cycle.

> **NOTE**
>
> If the number of measurements to be averaged (C) is entered as zero, then the average will be taken over one reading (i.e., zero defaults to one), (C) will default to 10,000 if entered as > 10,000. The number of measurements constant is initialized to four (C = 4) at power-up.

f) The Average is calculated and updated in memory as each reading is taken (up to 10,000). The average of "N" readings can be recalled before the average of " C " readings is displayed (if selected for display).

3.4.8.6 SYNC OUTPUT: As can be seen in Figure 3.7, a pulse appears at the SYNC output each time the display is updated. When "average" is selected for display, the pulse will occur only once per LAH average cycle. Refer to paragraph 3.4.14.2 for a description of the SYNC output signal.

3.4.8.7 APPLICATIONS: A general list follows:

a) Low Frequency noise (less than 6 Hz) can be averaged resulting in a "quieter" display.

b) Lowest and Highest values can be captured during long term testing.

c) Using LAH and the % function allows the user to quickly determine the maximum, minimum and average % deviation for a quantity of electronic components.

### 3.4.9 NULL Function.

3.4.9.1 The NULL Function is an ESC feature of the DMM that can be enabled manually from the keyboard or through the GPIB remote system.

3.4.9.2 The NULL Function calculates and displays the difference between each measurement value and a Null constant. When NULL is enabled from the keyboard, the number in the Numerical Input Buffer (see Figure 3.7) is stored as a NULL constant and subtracted from all future readings until changed or the NULL function is disabled by depressing the NULL key again. The NULL constant can be either the measurement value at the time NULL is enabled or a numerical value entered via the keyboard. A NULL constant can be entered from the keyboard when enabling Null operation or entered after the function is enabled. The operator can observe the Null constant in memory at any time by recalling it to the display.

3.4.9.3 To subtract the present reading from future measurements, simply depress the NULL key. The reading in the Numerical Input Buffer when the NULL key is depressed is stored as the Null constant.

3.4.9.4 To subtract a constant entered via the keyboard from each measurement value, execute the following keystrokes:

a) Depress the SHIFT key.

b) Key-in the numerics to be subtracted from each measurement value. This numeric will appear on the display as each key is depressed. If the Null constant is a resistance, enter the value in KΩ.

c) Depress the NULL key to store the numerical value as the Null Constant and simultaneously enable the Null Function.

3.4.9.5 To enter or modify the Null Constant after the Null Function is enabled, perform the following procedure:

a) If a measurement value is to be stored as the Null Constant, verify that a reading is presently in the display; if not, press the SINGLE or TRACK Key to take a measurement. Go to Step (c).

b) If a numerical constant is to be stored as the Null Constant, press the SHIFT Key and key-in the Null Constant with the numerical entry keys (these numerics will appear on the display). If the Null Constant is a resistance, enter the value in KΩ.

c) Depress the STORE key.

d) Depress the NULL key to enter the Null Constant into memory.

3.4.9.6 The NULL constant stored in memory can be recalled to the display anytime, with the two keystroke sequence RECALL and NULL.

3.4.9.7 The Null Function Applications are numerous but a few are listed as examples:

a) The measurement of line or load regulation of a DC power supply. The nominal DC output from the supply is substracted from its output under modified line or load conditions and the deviation displayed directly.

b) Cancellation of lead resistance in the measurement of low resistance values with a two-wire connection to the unknown resistance.

c) Addition or subtraction of a constant from the measured value. Addition is accomplished by entering the Null constant with a minus sign.

### 3.4.10 Percent Function.

3.4.10.1 The Percent Function complements the DMM's Extended Software Capability (ESC) features with the additions of percentage calculations when operating in the Volts and Ohms Functions. The Percent Function can be enabled manually from the keyboard or through the GPIB system.

3.4.10.2 The Percent Function calculates and displays the percentage deviation of each measurement and from a reference value (Percent Constant). The deviation calculation formula is:

$$\text{PERCENT DEVIATION} = \frac{\text{Measurement Value - Percent Constant}}{\text{Percent Constant}} \times 100$$

The Percent Function is enabled or disabled, by pressing the Percent (%) key when not preceded by the STORE or RECALL key. However, a non-zero percent constant must be stored to obtain meaningful results. The "%" annunciator indicates when the function is enabled.

3.4.10.3 The Percent Constant can be either a measurement reading or a numerical value entered via the keyboard. Note that an "ERROR 0" message is displayed, when a Percent Constant is not stored in memory prior to enabling the Percent Function. The operator can check the Percent Constant in memory by recalling it to the display, following the instructions listed in Table 3.4 and paragraph 3.4.7.

3.4.10.4 To store a measurement value or numerical constant as the percent constant, perform the following procedure:

a) If a measurement value is to be stored as the Percent Constant, verify that a reading is presently in the

display; if not, press the SINGLE or TRACK key to take a measurement. Go to step (c).

b) If a numerical constant is to be stored as the Percent Constant, press the SHIFT key and key-in the Percent constant with the numerical entry keys (these numerics will appear on the display).

c) Depress the STORE key.

d) Depress the % key to store the displayed number into memory. Note that pressing the % key did not enable or disable the Percent Function because it was preceded by the STORE key. If this procedure is performed while the Percent Function is enabled, the calculation and display of Percent Deviation will begin with the next reading.

3.4.10.5 Percentage Deviations too large to display normally will be displayed in Scientific Notation, (e.g., 1,000,000% displayed as 1.00E6). However, percent deviations equal to or greater than 1010% will result in an "ERROR 6" message. Other conditions related to the number of significant digits in the calculated value will also cause the percentage to be displayed in scientific notation.

### 3.4.11 Time Function.

3.4.11.1 The Time function adds another dimension to the capabilities of the DMM by bringing measurement and computation features under the control of the DMM's built-in digital clock. It also gives the user a very useful 96 hour clock which can be used when the DMM is not otherwise employed. The Time function can be configured to provide timed measurements with selectable Start time, Stop time, Interval, Subinterval, Number of Readings (N), and Present Time. Most applications will require only a subset of the Time function's full capabilities.

3.4.11.2 The Time function when used in conjunction with other Extended Software Capability Features, increases the DMM's applications. The following list describes typical applications:

a) Monitor an input signal at programmed intervals up to 96 hours and beyond.

b) Store all readings into the Data Buffer for later recall.

c) The sync output can sequence a scanner (such as Racal-Dana's Model 1200) to scan up to 99 inputs at controlled intervals and store the readings to the Data Buffer as well as output them to a GPIB printer.

d) When used in conjunction with LAH function, it can be used to average up to 10,000 readings taken at controlled intervals.

3.4.11.3 The TIME function key on the keyboard is a toggle switch which is depressed to toggle "ON" and depressed again to toggle "OFF". When the Time key is toggled ON, it puts the DMM into hold. When the Time key is toggled OFF, it puts the DMM in the continuous reading mode. The Time annunciator will indicate the status of the Time key. When programmed from the GPIB, the trigger status is not affected by enabling or disabling the Time function. Further GPIB programming details are presented in paragraph 3.5.23.

3.4.11.4 There are six memory locations that control the various ways the TIME function operates. These memory locations, referred to in Table 3.5, have the indicated designators and limitations.

**Table 3.5 - Time Register Codes**

| Name | Designator | Power-Up Initialization | Largest Value That The User Can Store | Comments |
|---|---|---|---|---|
| Start Time | Time 1 | 00.0000 | 99.5959 | |
| Stop Time | Time 2 | 99.0000 | 99.5959 | |
| Interval | Time 3 | 00.0000 | 99.5959 | 0 defaults to 1 second. |
| Subinterval | Time 4 | 00.0000 | 99.5959 | |
| N (Number of Readings per interval) | Time 5 | 1 | 99 | |
| Present Time | Time 6 | 00.0000 | 99.5959 | Begins counting at power-up. Increments to 00.0000 at 96 hrs. |
| Note: The format for Time numbers is XX.YYZZ where XX = hours, YY = minutes, ZZ = seconds. | | | | |

3.4.11.5 The Present Time Register is the most important of the six Time Function registers. At power-up the present time begins incrementing at one-second intervals until it reaches 95.5959 (95 hours, 59 minutes, 59 seconds.). One second later it resets to 00.0000 and begins incrementing again. Figure 3.8 shows the path taken by the Present Timer register as it approaches 96 hours on the time axis and then resets to zero. Note that the Present Time register always increments whether or not the Time function is enabled.

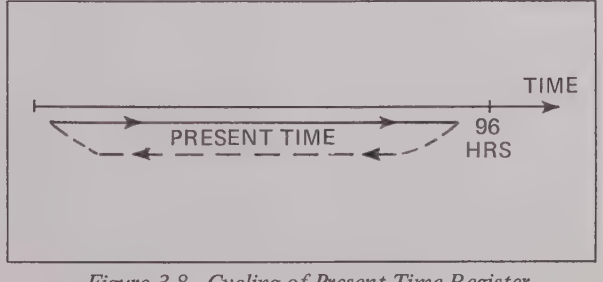



*Figure 3.8 - Cycling of Present Time Register*

3.4.11.6 The Start Time and Stop Time registers form a "window" during which readings can take place. As an example, Figure 3.9 shows the Start Time set to 20.0000 hours and the Stop Time set to 50.0000 hours. The example also shows how the Present Time has incremented past the Start Time, causing a reading to take place. Other readings may be triggered between start and stop times under control of the Interval, Subinterval, and N registers, which will be covered later.

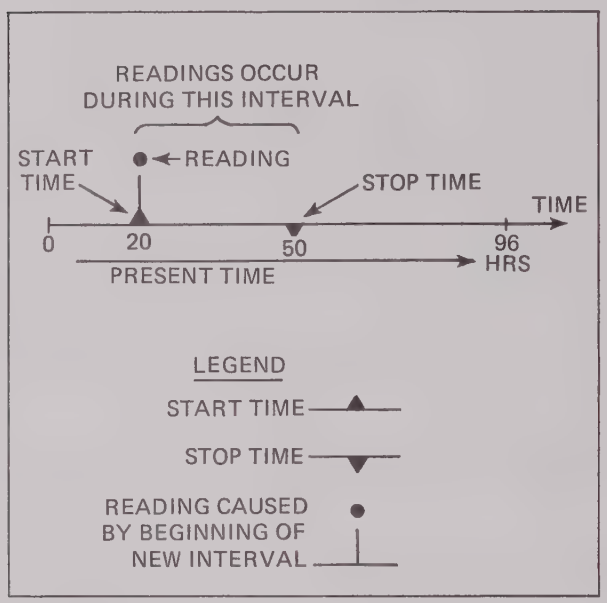



*Figure 3.9 - Use of Start and Stop Time Register*

3.4.11.7 Since the Present Time resets to zero at 96 hours, it is possible to set the Stop Time (or any other time register) at "infinity" on the time scale by storing a number greater than 95.5959 to the register in question. An example is shown in Figure 3.10, where the start time has been set to 30 hours and the stop time has been set to 99 hours, placing it "out of range" of the present time register. With these start/stop settings, reading(s) would begin at 30 hours and continue forever under control of the Interval, Subinterval and N registers.

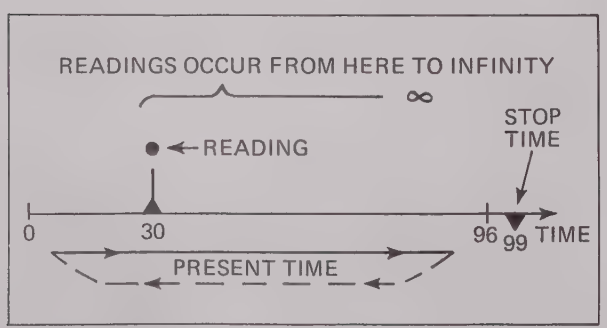



*Figure 3.10 - Setting Stop Time at Infinity*

3.4.11.8 Interval, Subinterval and N Registers: Once inside the Start-Time/Stop-Time window, the Interval, Subinterval and N registers control the triggering of readings. An example is shown in Figure 3.11, where the subinterval and N registers have been set to their power-up value and the Interval register is controlling the time between readings. Notice that once the Start Time is reached, the DMM's Interval register triggers a reading every Interval time until the Stop Time is reached.

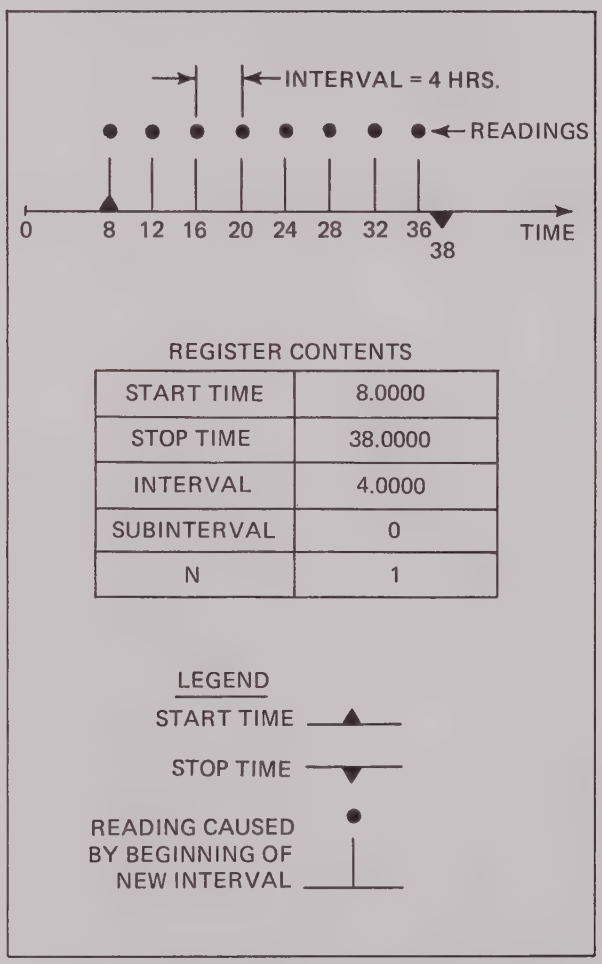
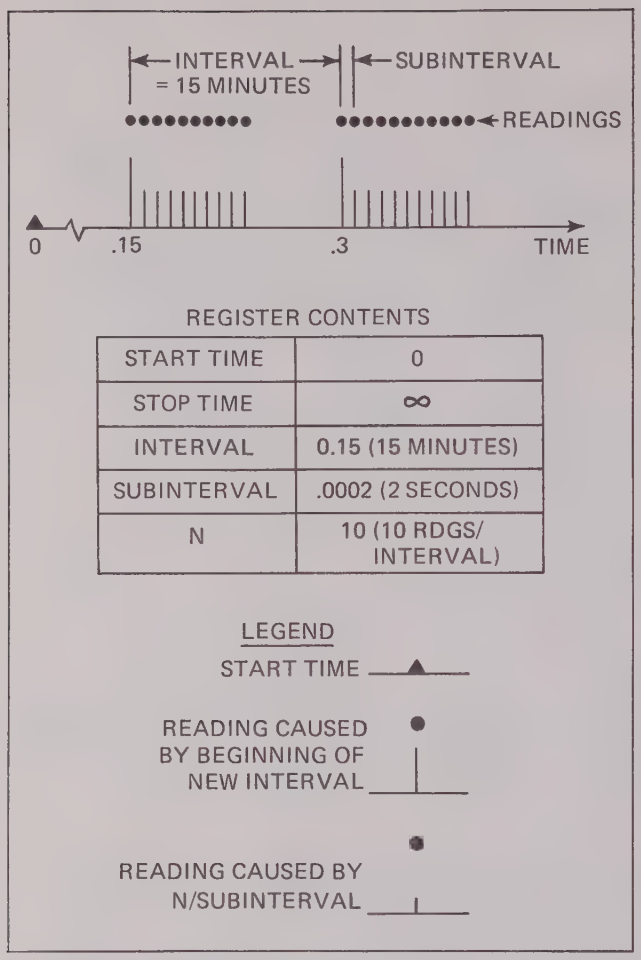



*Figure 3.11 - Example of Start, Stop, and Interval Registers*

3.4.11.9 Some applications require a read timing pattern similar to that shown in Figure 3.12. This read timing pattern is commonly used whenever a group of signals must be monitored within seconds of one-another periodically, as is the case when simultaneous temperature measurements must be made throughout a unit-under-test. Notice in this example that the Subinterval and N Registers are used to cause tight groups of 10 readings to occur every Interval time.




REGISTER CONTENTS

| | |
|---|---|
| START TIME | 0 |
| STOP TIME | ∞ |
| INTERVAL | 0.15 (15 MINUTES) |
| SUBINTERVAL | .0002 (2 SECONDS) |
| N | 10 (10 RDGS/ INTERVAL) |




*Figure 3.12 - Example of Interval, Subinterval and "N" Registers*

3.4.11.10 Before the Time function is enabled, all 6 Time registers should be set to their proper values. Section 3.4.7 details the procedure for entering and storing all 6 Time constants. Keep in mind that hours are entered before the decimal point, minutes and seconds after the decimal point. Any Time constant can be examined by using the key procedure listed in Table 3.3. Recalling the Present Time allows the DMM's front panel display to be used as a 96 hour clock.

3.4.11.11 Some further points should be kept in mind when using the Time function:

a) If the Time function is disabled when the Present Time crosses the Start Time, readings will take place starting (1) Interval Time beyond the point when the Time function is enabled and continuing at Interval times from thereon. This is shown in Figure 3.13 where 2 identical Time function setups yield different results because of differences when the Time function is enabled. In order to avoid problems in critical applications, make sure that the Time function is enabled before the Present time encounters the Start time.

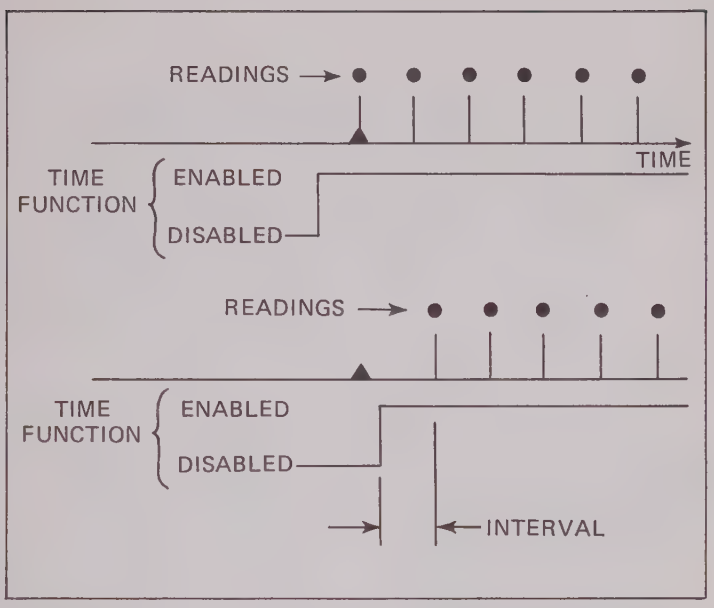
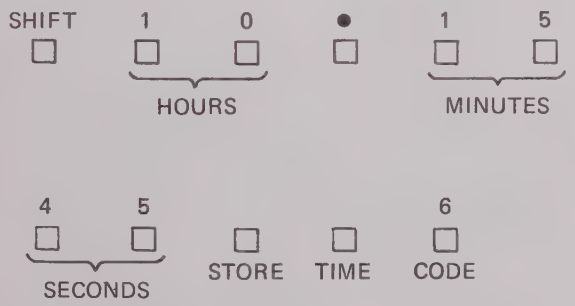



*Figure 3.13 - Effect of Enabling Time Function After Start Time*

b) The accuracy of the Time function is ± [(2 seconds/ hour) + 1 second].

c) Many front panel keyboard operations can disrupt the Time function. Therefore, the DMM should be completely set up before enabling the Time function.

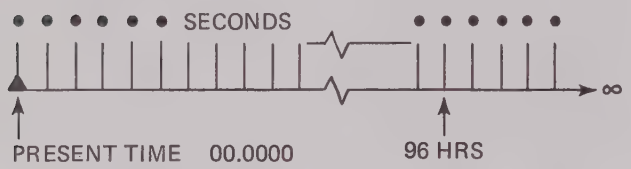
3.4.11.12 The following example lists the key strokes required to alter the Present Time (TIME6) to 10 hours, 15 minutes, and 45 seconds:




The SHIFT key enables the numeric key settings of 10 hours, 15 minutes and 45 seconds, this is followed by the STORE key, TIME key, and the last numeric entered sets the "N" register to be altered.

3.4.11.13 The following text represents a group of TIME Function examples and applications:

a) Pressing the TIME key without storing times in Time Registers will result in processing one reading per second (Time Registers are in their Power-up state). Note that TIME 3 (Interval) defaults to 1.0 second when no other value is stored.

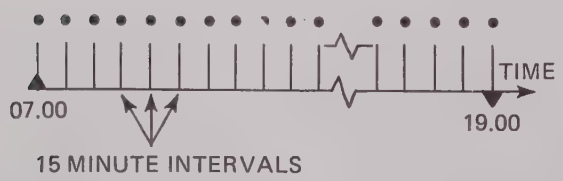



PRESENT TIME 00.0000
START TIME 00.0000
STOP TIME 99.0000
INTERVAL 00.0000
SUBINTERVAL 00.0000
N 1

b) For most applications the N and Subinterval will be left at their power-up values. As an example, suppose we wish to measure the AC line voltage every 15 minutes from 7:00 AM to 7:00 PM. The registers would be loaded as follows:

| | | |
|---|---|---|
| Start Time | (Time 1) | 07.0000 |
| Stop Time | (Time 2) | 19.0000 |
| Interval | (Time 3) | 00.1500 |
| Present Time | (Time 6) | Some real-time before 07.000. |

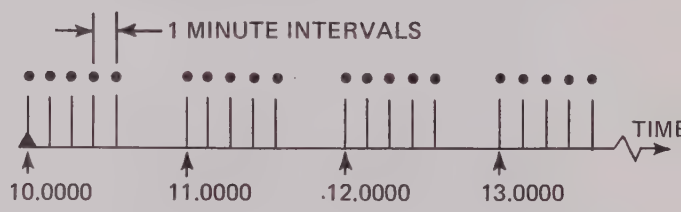
Graphic example:




c) To process 5 readings taken one minute apart, every hour, on the hour, starting at 10:000; the registers are set up as follows:

| | | |
|---|---|---|
| Present Time | (Time 6) | Some real-time before 10:00. |
| Start Time | (Time 1) | 10.0000 |
| Stop Time | (Time 2) | 99.0000 |
| Interval | (Time 3) | 01.0000 |
| N | (Time 5) | 05.0 |
| Subinterval | (Time 4) | 00.0100 |

Graphic example:




## 3.4.12 Program and Data Buffers.

3.4.12.1 The DMM 5004 contains a large area of Random Access Memory (RAMS U22 and U31) which is dedicated to the storage of instrument settings and readings. The instrument settings which refer to the position of all controls are stored in the Program Buffer and the readings which the DMM generates are stored in the Data Buffer.

3.4.12.2 THE PROGRAM BUFFER.

3.4.12.2.1 The Program Buffer allows the user to:

a) STORE ten complete instrument settings either as keyboard inputs or as GPIB inputs. The stored instrument settings can include Function, Range, Trigger, NULL, LAH, Percent, Time and numeric constants associated with the above mentioned ESC features.

b) In any sequence, RECALL the settings which were previously stored into the Program Buffer.

3.4.12.2.2 The ten Program Buffer registers will power-up in an 'empty' or initialized state, therefore instrument settings must be stored into the buffer before attempting to recall "program settings" from the buffer. To store a setting into the program buffer from the keyboard, (GPIB procedure is described in paragraph 3.5.9) the following procedure is used:

a) Keyboard Input: Program the DMM to the setting that will be stored in the buffer. For example, if Buffer program No. 9 will be DC, Auto-range and LAH function, depress the DC, AUTO and LAH keys, and continue with (b) next.

b) Press STORE Key.

c) Press SHIFT Key.

d) Press 0 . . 9 key as required.

During step d, the 7-segment display will display the message "ProGX" where X is the selected storage location (0-9).

3.4.12.2.3 There are some points to consider when "storing" programs to the Program Buffer:

a) Whenever a program is stored to the program buffer, the Data Buffer is cleared.

b) Programs can be redefined at any time. For example, the Program No. 9 contents can be changed to some other setting by first selecting the appropriate functions (using keyboard or GPIB) and then storing to program No. 9 again.

c) Once a program location is stored, it remains defined until the power is switched OFF to the DMM.

d) If the operator plans to use the Data Buffer, he should avoid storing programs to more program locations than necessary, otherwise the Data Buffer will become restricted in size. For further details, refer to paragraph 3.4.12.4, the Buffer Organization.

3.4.12.2.4 The following procedure is used to RECALL a program stored in the Program Buffer:

a) Press RECALL key.

b) Press SHIFT key.

c) Press 0 . . 9 key as required.

During step "C" the 7-segment display will show the message "ProGX" where X is the selected program location (0-9). When the RECALL procedure is completed, the DMM will immediately assume the settings which have been recalled from the program buffer.

3.4.12.2.5 Consider the following points when "recalling" programs from the Program Buffer.

a) Whenever a program is recalled, the LAH function is cleared. This is done so that if the recalled program makes use of LAH, the LAH constants which are generated will not be affected by the previous instrument settings.

b) All of the Time Function registers will be affected by a program recall with the exception of T6, the present time.

3.4.12.3 THE DATA BUFFER.

3.4.12.3.1 The Data Buffer allows the user to:

a) Store over 130 readings for later use.

b) Recall these readings to the display or over the GPIB.

c) The Data Buffer can store over 130 readings when the Program Buffer is not in use and over 45 readings can be stored when all 10 Program Buffers are used. This is described in Section 3.4.12.4 which discusses Buffer Organization.

d) The Data Buffer is a first-in-first-out (FIFO) register; therefore during recall location Ø contains the first stored reading, location 1 contains the second, etc.

3.4.12.3.2 Unlike most ESC features of the DMM, the Data Buffer cannot be disabled or "turned-off"; therefore it is always either in the storing process or the register capacity is completely filled. The two operations which can be performed on the buffer are clearing (CE) and recalling (RECALL). Everytime that a reading is taken, it is first processed by other ESC functions such as NULL, %, and LAH. Then the Data Buffer is checked for space availability. If available, a copy of the processed reading is stored into the buffer. The buffer will remain filled until cleared and the readings from the buffer can be recalled any number of times to the display or the GPIB.

3.4.12.3.3 The Data Buffer will power-up in the cleared or empty state. Therefore data readings must be taken or accumulated in the buffer before attempting to recall the data readings from the Data buffer otherwise the DMM will either show mostly a blank display to a bench operator or send an SRQ to the controller if in remote. In order to prevent the Data Buffer from being accidentally cleared from the keyboard (GPIB procedure is described in paragraph 3.5.28) a time delay is inserted in the Keyboard Buffer Clear routine. To clear the Data Buffer, the BUFF key must be depressed until the seven-segment display shows the entire word "ClrbuF". This should take about five seconds.

3.4.12.3.4 The recalling of readings from the Data Buffer to the display (GPIB procedure is described in paragraph 3.5.9) can be accessed sequentially and displayed on the DMM's front panel by following the procedure listed below:

a) Press the RECALL key. The display will show "rCL".

b) Press the BUFF key. A number will appear at the right edge of the display, assuming that the buffer is not completely emptied or cleared. This number is the buffer address that will be recalled when the BUFF key is released. Depressing the BUFF key for two seconds enables the displayed address to increment and will eventually reach the point where the last reading was stored. The displayed address will then return to zero and begin incrementing up again. If the user wishes to initialize the recall process to address the first constant, the procedure listed next should be followed.

   1) DO NOT DEPRESS THE RECALL KEY.

   2) Depress the BUFF key and monitor the display.

   3) The display will show "Clr" as the BUFF key is depressed. Release the key after appearance of the r in "Clr".

   4) This will initialize the recall address to 00.

3.4.12.4 BUFFER ORGANIZATION.

3.4.12.4.1 By allowing the two buffers to share the same memory, more readings can be stored into the data buffer (over 130) when the program buffer is not in use. This is best described by reviewing Figure 3.14A and Figure 3.14B which show the relation between Program and Data buffers.

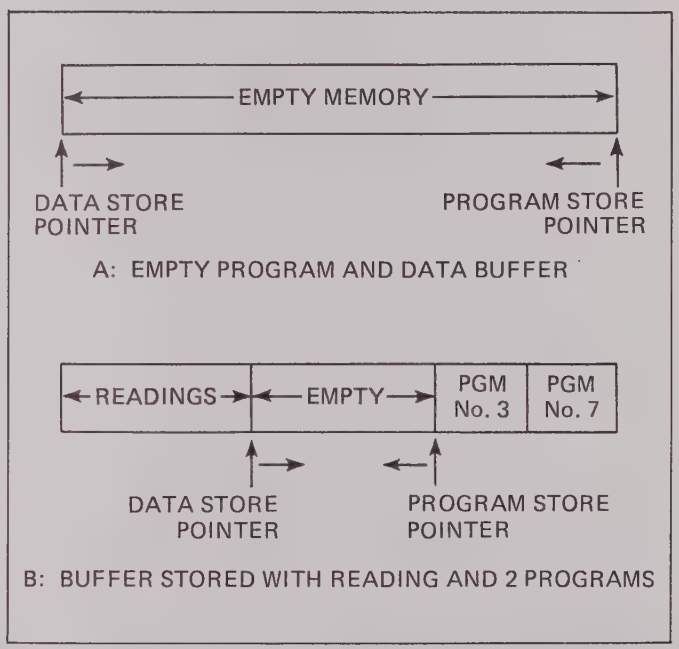



*Figure 3.14 - Program and Data Buffer Storage*

3.4.12.4.2 There are two pointers associated with the buffer operation as shown in Figure 3.14. The Program Store pointer points to the next available program storage location, moving right to left as programs are stored. The Data Store pointer points to the next available data storage, moving left to right as readings are stored. The Data Store pointer bumps into the Program Store pointer when the memory block is full. Hence, no more readings are stored until the data buffer is cleared.

3.4.12.4.3 When the Program and Data Buffers are used simultaneously, the Data Buffer must operate with a smaller memory space, as shown in Figure 3.14B. From the figure, it is noted that program No. 7 and program No. 3 have been stored in the buffer. This has reduced the number of readings which can be stored.

3.4.12.4.4 Data Buffer size can be determined when Data and Program Buffers are used simultaneously. The following

equation can be used to determine the number of readings which can be stored:

No. of Readings = 130 – (7·N)

where N is the number of programs which were stored (N = 2 in Figure 3.14B).

### 3.4.13 Error Messages.

3.4.13.1 Error messages are classified in two categories, General Error Messages and GPIB Error Messages. The general error messages with numerics 0 through 9 apply to local and remote operations. GPIB error messages with numerics 10 through 13 apply only to remote operation.

3.4.13.2 For local operation, the DMM employs the 7-segment display to exhibit the error message code numbers. The error message numbers and explanations are listed in Table 3.6; General and Remote Error Messages.

3.4.13.3 For remote GPIB operation, the DMM transmits an SRQ to the controller; the controller replies with the "Y" program code to the DMM to request the error message number. The remote error message numbers and explanations are listed in Table 3.6. Refer to Section 3.5.20 for further explanation of the "Y" program code.

**Table 3.6 - General and Remote Error Messages**

| Error Message No. | Error Message |
|---|---|
| | GENERAL ERROR MESSAGES |
| 0 | Percent Constant = 0 during Percent calculations |
| 1 | Not in the DC function, 0.1 range when executing DIGITAL ZERO command. |
| 2 | Attempting to execute DIGITAL ZERO command with an input voltage applied or the input open-circuited. Connect a short across input terminals and repeat DIGITAL ZERO command. |
| 3 | The microprocessor's on-board RAM is defective (U35 on the motherboard). |
| 4 | The contents of the non-volatile memory have been disrupted, therefore the instrument's calibration should be verified. |
| 5 | A digitizer offset greater than 1000 digits was measured during execution of DIGITAL ZERO command. |
| 6 | Percent Deviation of $\geq 10^{10}$% while in the Percent Function. |
| 7 | The RAM is defective, U22 and/or U31 on the motherboard. |
| 8 | An attempt was made to store a overload reading to a register inside the DMM or an attempt was made to store > 99.5959 hours into a Time function register. |
| 9 | At attempt was made to recall a program setting from the program buffer before setting was stored to the program buffer. |
| | GPIB ERROR MESSAGES |
| 10 | Recall of a constant whose value is empty set, for example - sending an "L7" command to a DMM will cause this error if the LOW, AVERAGE, and HIGH constants are the empty set (no readings taken yet.) |
| 11 | Triggered too fast or too often. |
| 12 | Syntax error during GPIB programming. |
| 13 | Option not installed. |

### 3.4.14 DMM Pulse Level/Timing Characteristics.

3.4.14.1 EXTERNAL TRIGGER.

3.4.14.1.1 The signal level and timing requirements for the external trigger are presented in Figure 3.16A. These timing requirements are not critical when in local control as the DMM interprets a tight group of external triggers as a single trigger command and the rise and fall time specifications stated in Figure 3.16A do not apply, due to this internal debouncing. This allows the use of mechanical foot switches and other "noisy" signal sources with good results. When in remote, all external triggers are treated individually and two or more closely spaced triggers will cause the DMM to issue an SRQ to the bus and make an error message available to the controller.

3.4.14.2 SYNC OUTPUT.

3.4.14.2.1 The DMM provides a synchronizing output pulse from a BNC connector on the rear panel. Refer to Figure 3.2. This pulse, timing shown in Figure 3.16B, indicates when the DMM has finished a reading or a sequence of readings. This output pulse can be used to sequence a signal scanner or other device as shown in Figure 3.16C.

3.4.14.2.2 When Autorange is selected, the sync output will not appear until the DMM has completed autoranging, and has taken the reading on the proper range.

## 3.5 SYSTEM OPERATION.

3.5.1 This subsection presents information on the operation of the 5004 in a system.

### 3.5.2 General Purpose Interface Bus.

3.5.2.1 The IEEE-488-1978 (GPIB) Interface provides remote programming for all controls and the output of data from the DMM. Inputs and outputs are made via a 24 pin connector, (see Figure 3.15), located on the rear panel. The pin location, line identification, and operation of the GPIB are in compliance with IEEE-STD-488-1978. The GPIB provides interface capability with other instruments and with a controller also utilizing the "interface bus" structure. Connector pin assignments are shown in Figure 3.17. The IEEE-488-1978 subsets available are listed in Table 3.7.

3.5.2.2 By assigning a unique address to the DMM, it can be "called up" by the controller or another device on the bus without interfering with other units on the bus. Switches located on the rear panel of the DMM permit the programming of the instrument address. The coding used for the address is binary. Any one of 31 codes can be used for the address of an instrument, but a total of 15 is the maximum number of devices that can be used on one bus.

Table 3.7 - IEEE-488-1978 Standard Interface Subset Capability

| GPIB Subset | Description | Applicable Capability |
|---|---|---|
| SH1 | Source Handshake | Complete Capability |
| AH1 | Acceptor Handshake | Complete Capability |
| T5 | Talker | Complete Capability<br>(1) Basic Talker<br>(2) Serial Poll<br>(3) Talk only Mode<br>(4) Unaddress if MLA |
| TE0 | Extended Talker | None |
| L4 | Listener | Complete except Listen Only<br>(1) Basic Listener<br>(2) Unaddress if MTA |
| LE0 | Extended Listener | None |
| SR1 | Service Request | Complete Capability |
| RL1 | Remote/Local | Complete Capability<br>(1) REN - Remote Enable<br>(2) LLO - Local Lockout<br>(3) GTL - Go to Local |
| PP0 | Parallel Poll | No Capability |
| DC1 | Device Clear | Complete Capability<br>(1) DCL - Device Clear<br>(2) SDC - Selected Device Clear |
| DT1 | Device Trigger | Complete Capability<br>GET - Group Execute Trigger |
| C0 | Controller | No Capability |
| E1 | Open Collector Bus Drivers | |

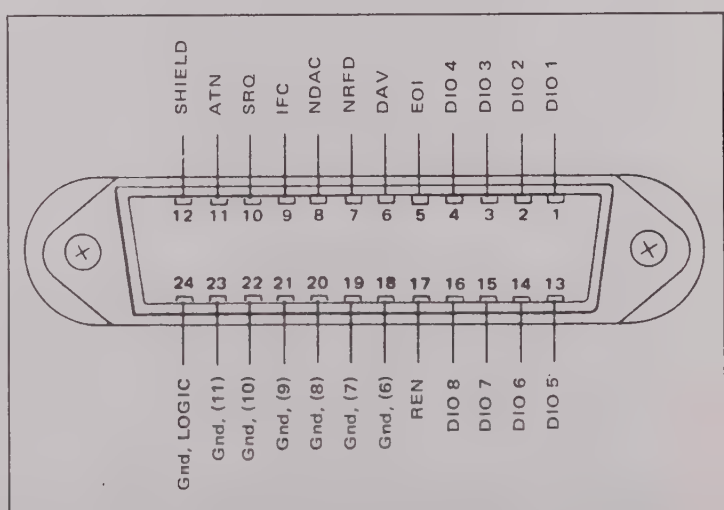



*Figure 3.15 - GPIB Connector (Rear Panel)*

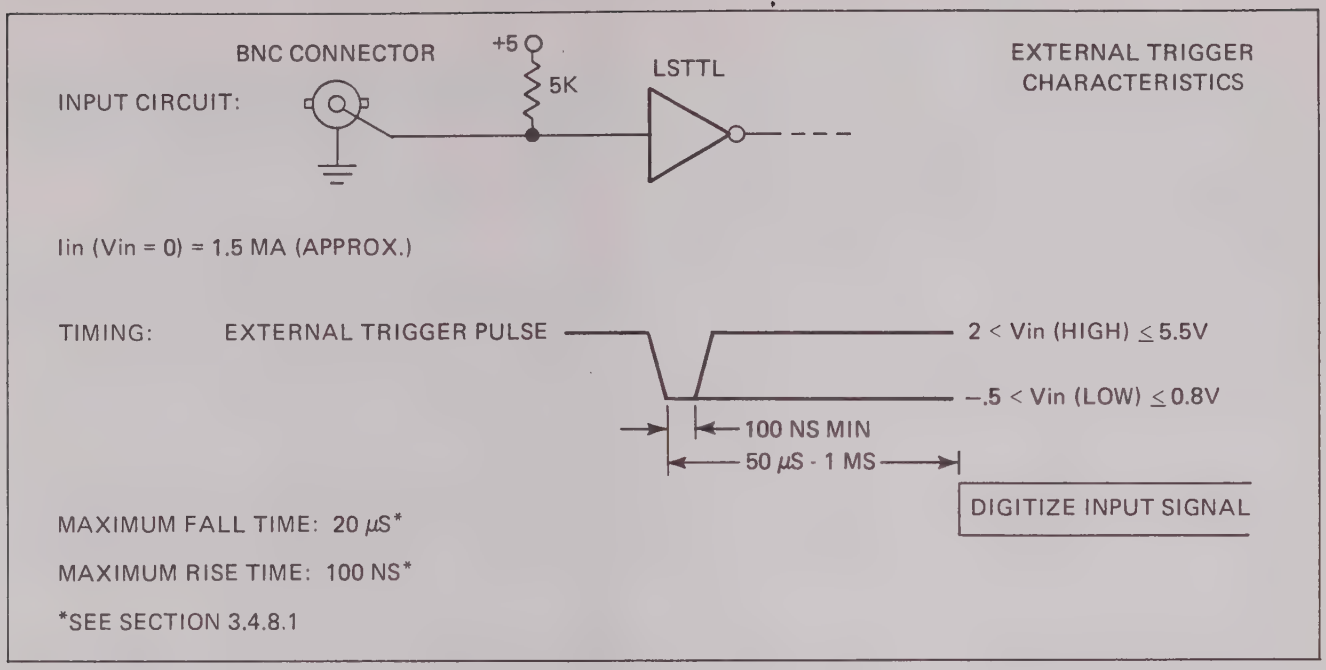



*Figure 3.16A - External Trigger Characteristics*

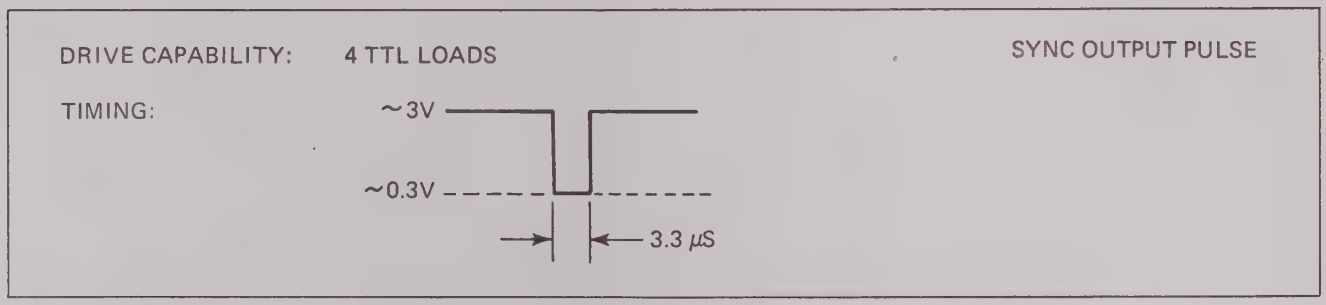



*Figure 3.16B - Sync Output*

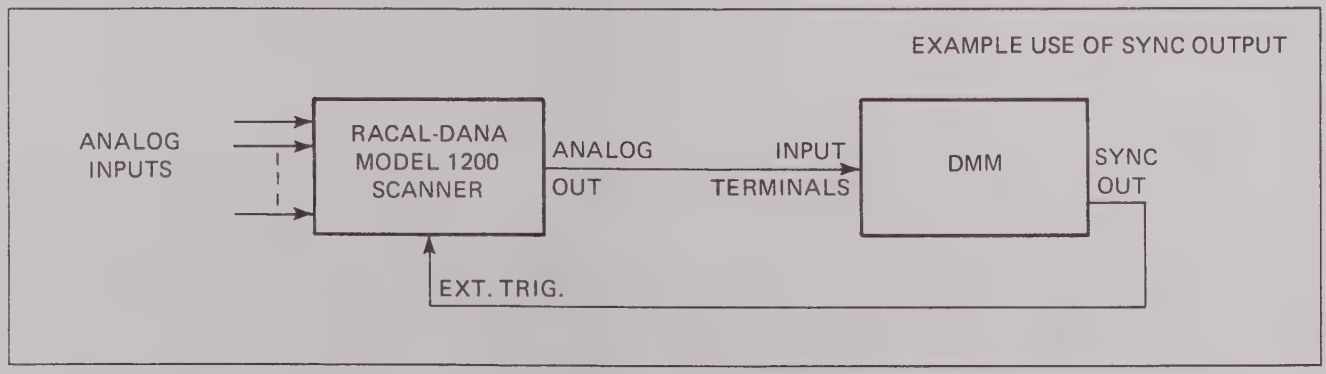



*Figure 3.16C - Sync Application*

### 3.5.3 GPIB Description.

3.5.3.1 Of the twenty-four lines available at the connector (shown in Figure 3.15) seven are grounds, one is a shield, and the remaining 16 lines are the signal lines. All of the signal lines are either input or output lines and have the following characteristics:

Logic Levels: (1 = Low = ≤ .8V) (0 = Hi = ≥ 2.0V)
Input Loading: Each input ∼ two TTL loads

Output: The output is capable of driving 15 interface bus loads. It consists of an open collector driver and is capable of sinking 48 mA with a maximum voltage drop of 0.5 volts. See IEEE-488 Electrical Specifications.

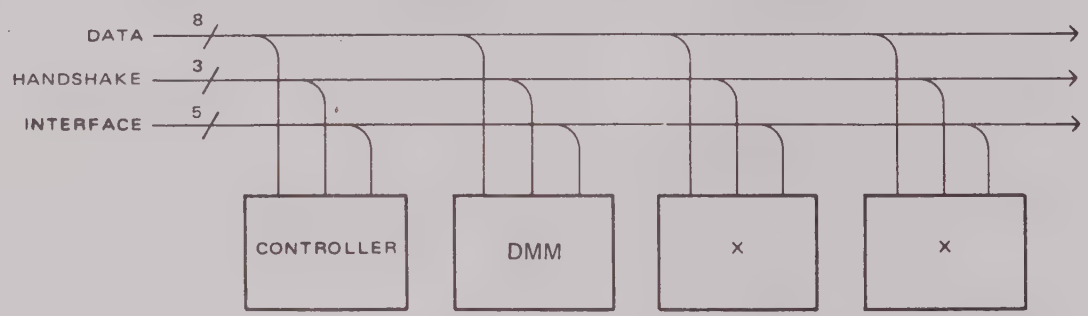
3.5.3.2 The signal lines, as shown in Figure 3.17 consist of three functionally separate sets: Data, Handshake and Interface.

3.5.3.3 DATA.

3.5.3.3.1 The data lines consist of lines DI0-1 through DI0-8. These lines are the lines over which data flows between all instruments on the bus in bit parallel, byte serial form.

3.5.3.4 HANDSHAKE.

3.5.3.4.1 The transfer lines consist of: DAV (data valid), NDAC (not data accepted), and NRFD (not ready for data). These lines provide communication (between the instrument that is talking and the instruments that are listening) to




| PIN | | | PIN | |
|---|---|---|---|---|
| 1 | DI0-1 Data In/Out Bit 1 (LSB) | DATA LINES ARE USED TO TRANSFER DATA FROM ONE INSTRUMENT TO ANOTHER | 12 | SHIELD |
| 2 | DI0-2 Data In/Out Bit 2 | | 18 | GND |
| 3 | DI0-3 Data In/Out Bit 3 | | 19 | GND |
| 4 | DI0-4 Data In/Out Bit 4 | | 20 | GND |
| 13 | DI0-5 Data In/Out Bit 5 | | 21 | GND |
| 14 | DI0-6 Date In/Out Bit 6 | | 22 | GND |
| 15 | DI0-7 Data In/Out Bit 7 | | 23 | GND |
| 16 | DI0-8 Data In/Out Bit 8 | | 24 | LOGIC GND |
| 6 | DAV (DATA VALID) | HANDSHAKE LINES OPERATE IN A PROPER TIME SEQUENCE FOR COMPLETE COMMUNICATION BETWEEN INSTRUMENTS | 25 | NOT USED |
| 7 | NRFD (NOT READY FOR DATA) | | | |
| 8 | NDAC (NOT DATA ACCEPTED) | | | |
| 5 | EOI (END OR IDENTIFY) | INTERFACE LINES ARE USED TO PROVIDE AN ORDERLY FLOW OF INFORMATION BETWEEN UNITS | | |
| 9 | IFC (INTERFACE CLEAR) | | | |
| 10 | SRQ (SERVICE REQUEST) | | | |
| 11 | ATN (ATTENTION) | | | |
| 17 | REN (REMOTE ENABLE) | | | |

*Figure 3.17 - Interface Signal Pin Assignments*

synchronize the flow of information across the eight data lines. These lines derive their nomenclature from their meaning in the low or one state (eg: when NRFD is low the device is Not Ready For Data).

a. DAV. Signifies that valid information is available on the data lines.

b. NRFD. Signifies that the instrument is not ready to accept information.

c. NDAC. Signifies that the information is not accepted by the acceptor.

3.5.3.5 INTERFACE.

3.5.3.5.1 The five interface lines coordinate the flow of information on the bus.

a. Interface Clear
'IFC'. Places the DMM interface in the IDLE state. (Untalk, Unlisten).

b. Attention
'ATN'. Indicates the nature of information on data lines during a handshake transfer sequence. Low indicates data lines carry interface commands; high indicates that the data lines carry data.

c. Remote Enable
'REN'. Arms instrument to select Remote Operation. (Low for Remote)

d. Service Request
'SRQ'. Service request signal line. Signals the controller that a peripheral or bus member wants attention for such purposes as transmitting measurement, status or condition information to the bus controller.

e. End or Identify
'EOI'. End or Identify signal. Used for two purposes: (1) to signify the end of a message and (2) to signal bus peripherals to set the I/O bit assigned for parallel poll identification process.

### 3.5.4 Handshake.

3.5.4.1 The handshake is the process by which each data byte is transferred from the source to the acceptor. Figure 3.19 illustrates the sequential relationship between the DAV, NRFD, and NDAC lines (used to transfer data bytes). Figure 3.18 illustrates the handshake flow chart.

### 3.5.5 Address Assignment.

3.5.5.1 When the DMM is used as a system instrument it must be assigned an address as a bus member. The instrument is equipped with an address switch located on the rear panel which enables the user to assign it one of 31 decimal addresses. The decimal addresses available are the numbers 00 through 30.

3.5.5.2 Table 3.8 contains all of the information required for setting the instrument address switch and for determining the talk and listen address codes used in programming the controller.

3.5.5.3 Refer to Table 3.8 and note that the right hand column shows the decimal addresses available for assignment to the DMM. The column titled Address Switch Setting illustrates the positions of the switches for each decimal address. To set the address on the instrument at the desired decimal address, refer to Table 3.8, and set the switches on the address switch to the pattern shown in the Address Switch column of the table.

3.5.5.4 As an aid in setting the address switches, the decimal address may be displayed on the DMM readout by holding the "Local" key down. The address switches may then be set until the desired address appears on the display. Turning on the "Talk Only" switch will cause the displayed address to be 64 or greater. This illegal address is displayed to alert the user that the DMM is in the "talk only mode".

3.5.5.5 Once the instrument has been assigned an address, and the address switch has been set, the controller may address the instrument as a talker or as a listener by transmitting the appropriate ASCII character on the data lines. The Data Lines column shows the 7 bit binary code required for each talk and listen address assigned to the instrument. These are the codes the controller must transmit to establish the talker/listener condition of the DMM. Note that there are two address codes used for each decimal address. Each of these address codes constitutes a different ASCII character. For example, if it is desired to use the decimal address 02, the address switch on the rear panel of the instrument is set to the pattern shown in Table 3.8. As shown in the table, the talk address is the ASCII character " and the listen address is the ASCII character B. Note that the only difference in the binary code in each case is the state of data lines D6 and D7.

3.5.5.6 Table 3.8 illustrates the data line code in binary form for each decimal address. Again, using the example for decimal address 02, note that bits D1 through D5 are the same for both talk and listen address and that the only difference is in bits D6 and D7.

### 3.5.6 Bus Operation Sequence.

3.5.6.1 The transmission of programming instructions to the DMM and the subsequent transmission of measurement data to the controller are accomplished by transmitting programming instructions as outlined in the bus operation sequence in Table 3.9. Table 3.9 and the accompanying timing chart (Figure 3.19) illustrate the sequence of the transmission of device dependent messages to the DMM which cause it to measure the voltage applied to the input and then transmit the resultant measurement data to the controller via the interface bus.

3.5.6.2 Note that the left hand column of Table 3.9 contains line numbers. These are used for reference purposes throughout the following description of the bus operation sequence. The column titled Handshake Lines indicates the high/low condition of the handshake lines at various points throughout the two-way transmission of information. In a similar fashion the columns titled Interface Lines and Data Lines contain entries reflecting the state of the interface lines and data lines during operation. The column titled Meaning or Function contains entries explaining the purpose of each operational step during the data transfer.

3.5.6.3 A timing chart is included to illustrate the condition of each individual bus line at each stage of the data transfer operation. Note that the timing chart includes numbers adjacent to each level change. These numbers refer to the individual line entries of the table.

3.5.6.4 The measurement operation used in Table 3.9 is a simple voltage measurement. The measurement parameters are as follows: Function DC volts, Range 10 volts, Trigger continuous. Note that the measurement parameters are shown in the meaning or function column of the table in lines 17 through 22 and that the program string required to perform this measurement is F1R5T1. The program string will include a carriage return and line feed, but in this case this command is automatically transmitted by the Hewlett Packard 9825.

3.5.6.5 For purposes of this example it is assumed that the DMM has been assigned the decimal address 02 and that the controller is a Hewlett Packard 9825 calculator with a talk address U. It is further assumed that both the controller and the DMM are system connected, turned on and operational.

3.5.6.6 Table 3.9 shows the sequence of bus operation. Lines 1 through 13 show the detailed operation of the bus for one handshake cycle (ie: the transmission of one ASCII character as a bus message). Lines 14 through 44 do not indicate the detail for each handshake cycle; they indicate only the transmission of the characters required for the programming commands and the subsequent transmission of the data by the DMM. Each transmission by the controller or the DMM, shown in lines 14 through 44, requires the handshake cycle illustrated by line entries 1 through 13 of the table.

3.5.6.7 Refer to Table 3.9, line 1, and note that the first operation performed is the setting of the Remote Enable (REN) line to the low state. As explained in the table, this operation arms the bus members to go to the remote mode. The controller then transmits the interface clear (IFC) signal which stops bus activity and the attention (ATN) line is set low indicating that the next data byte placed on the bus by the controller will be a Bus Message. Note in the timing chart that when the ATN line is set low (3) that the DMM responds by setting the NRFD line high (4). This response by the DMM indicates that it is now ready to accept data.

3.5.6.8 When the DMM transmits the ready for data signal by setting the NRFD line high (line 4 of Table 3.9) the controller puts the bus message UNL on the data lines. As shown in line 5 of the table this is the ASCII character ?. The unlisten message is a universal message understood by all bus members as the command "unlisten". Having placed the data character on the lines, the controller now says the data is valid by setting the DAV line low (6). The DMM then says "I'm going to accept the data now on the data lines; don't change the data lines". The DMM then reads the data lines (8) and acknowledges acceptance of the data by setting the NDAC line high (9). The controller then removes the data valid signal (10), removes or changes data (11) and the DMM removes the data accepted signal from the bus (12).

3.5.6.9 At this point, one ASCII character has been transmitted by the controller to the DMM and the DMM is now ready to accept a new data byte. It indicates this (13) by setting the NRFD line high. The controller now puts the next character on the data line and the handshake cycle for the transfer of the character is repeated. The next character transmitted by the controller is the ASCII character U which is the talk address of the Hewlett-Packard 9825 calculator. As indicated in Table 3.9, by transmitting this character the calculator is making itself a talker. The next character transmitted is the quotation mark which is the listen address of the DMM when it has been assigned the decimal address 02.

3.5.6.10 Lines 16 through 24 of the table illustrate the sequence of transmission of the program string which instructs the DMM to make the DC voltage measurement. Lines 26 and 29 of the table indicate the end of transmission with the characters CR (carriage return) and LF (line feed). Note that at line 16 of the table the controller sets the ATN line high indicating that the program string to follow in lines 17 through 24 are device dependent messages.

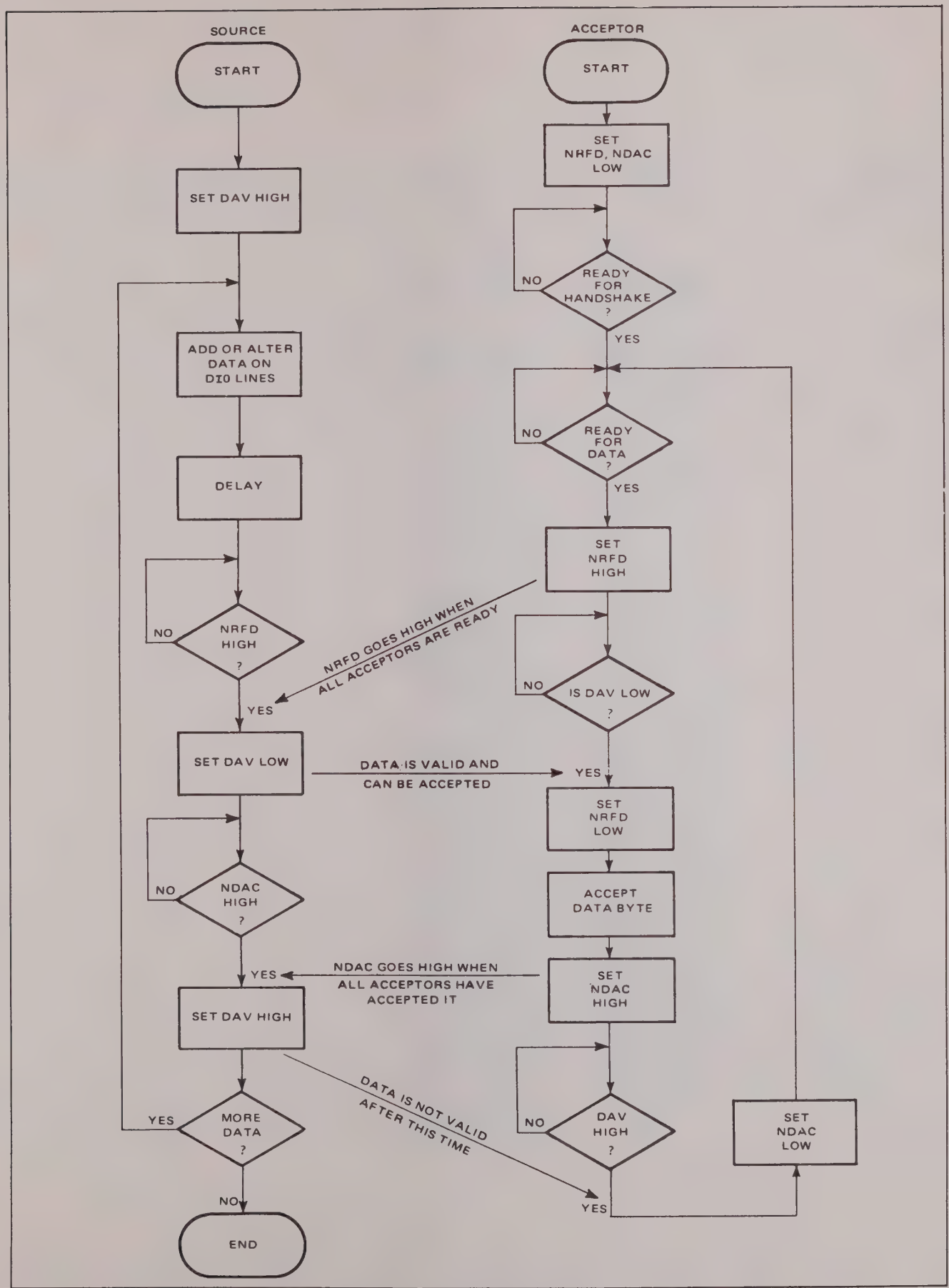
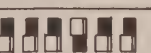



*Figure 3.18 - Handshake Flow Chart*

Table 3.8 - Instrument Address Selector

| ASCII CHARACTERS | | DATA LINES | | | | | | | ADDRESS SWITCH SETTING | DECIMAL ADDRESS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | | |
| TALK | LISTEN | TALK | LISTEN | ADDRESS | | | | | TALK ONLY (1) / (0) — A5 A4 A3 A2 A1 | |
| | | | | 16 | 8 | 4 | 2 | 1 | | |
| | SP | 0 | 1 | 0 | 0 | 0 | 0 | 0 | | 00 |
| @ | | 1 | 0 | 0 | 0 | 0 | 0 | 0 | | |
| | ! | 0 | 1 | 0 | 0 | 0 | 0 | 1 | | 01 |
| A | | 1 | 0 | 0 | 0 | 0 | 0 | 1 | | |
| | " | 0 | 1 | 0 | 0 | 0 | 1 | 0 | | 02 |
| B | | 1 | 0 | 0 | 0 | 0 | 1 | 0 | | |
| | # | 0 | 1 | 0 | 0 | 0 | 1 | 1 | | 03 |
| C | | 1 | 0 | 0 | 0 | 0 | 1 | 1 | | |
| | $ | 0 | 1 | 0 | 0 | 1 | 0 | 0 |  | 04 |
| D | | 1 | 0 | 0 | 0 | 1 | 0 | 0 | | |
| | % | 0 | 1 | 0 | 0 | 1 | 0 | 1 | | 05 |
| E | | 1 | 0 | 0 | 0 | 1 | 0 | 1 | | |
| | & | 0 | 1 | 0 | 0 | 1 | 1 | 0 | | 06 |
| F | | 1 | 0 | 0 | 0 | 1 | 1 | 0 | | |
| | APOSTROPHE | 0 | 1 | 0 | 0 | 1 | 1 | 1 | | 07 |
| G | | 1 | 0 | 0 | 0 | 1 | 1 | 1 | | |
| | ( | 0 | 1 | 0 | 1 | 0 | 0 | 0 | | 08 |
| H | | 1 | 0 | 0 | 1 | 0 | 0 | 0 | | |
| | ) | 0 | 1 | 0 | 1 | 0 | 0 | 1 | | 09 |
| I | | 1 | 0 | 0 | 1 | 0 | 0 | 1 | | |
| | * | 0 | 1 | 0 | 1 | 0 | 1 | 0 | | 10 |
| J | | 1 | 0 | 0 | 1 | 0 | 1 | 0 | | |
| | + | 0 | 1 | 0 | 1 | 0 | 1 | 1 | | 11 |
| K | | 1 | 0 | 0 | 1 | 0 | 1 | 1 | | |
| | , | 0 | 1 | 0 | 1 | 1 | 0 | 0 | | 12 |
| L | | 1 | 0 | 0 | 1 | 1 | 0 | 0 | | |
| | - | 0 | 1 | 0 | 1 | 1 | 0 | 1 | | 13 |
| M | | 1 | 0 | 0 | 1 | 1 | 0 | 1 | | |
| | . | 0 | 1 | 0 | 1 | 1 | 1 | 0 | | 14 |
| N | | 1 | 0 | 0 | 1 | 1 | 1 | 0 | | |
| | / | 0 | 1 | 0 | 1 | 1 | 1 | 1 | | 15 |
| O | | 1 | 0 | 0 | 1 | 1 | 1 | 1 | | |

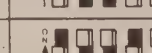
| ASCII CHARACTERS | | DATA LINES | | | | | | | ADDRESS SWITCH SETTING | DECIMAL ADDRESS |
|---|---|---|---|---|---|---|---|---|---|---|
| | | $D_7$ | $D_6$ | $D_5$ | $D_4$ | $D_3$ | $D_2$ | $D_1$ | | |
| TALK | LISTEN | TALK | LISTEN | ADDRESS | | | | | TALK ONLY (1) / (0) — A5 A4 A3 A2 A1 | |
| | | | | 16 | 8 | 4 | 2 | 1 | | |
| | Ø | 0 | 1 | 1 | 0 | 0 | 0 | 0 | | 16 |
| P | | 1 | 0 | 1 | 0 | 0 | 0 | 0 | | |
| | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | | 17 |
| Q | | 1 | 0 | 1 | 0 | 0 | 0 | 1 | | |
| | 2 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | | 18 |
| R | | 1 | 0 | 1 | 0 | 0 | 1 | 0 | | |
| | 3 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | | 19 |
| S | | 1 | 0 | 1 | 0 | 0 | 1 | 1 | | |
| | 4 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | | 20 |
| T | | 1 | 0 | 1 | 0 | 1 | 0 | 0 | | |
| | 5 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | | 21 |
| U | | 1 | 0 | 1 | 0 | 1 | 0 | 1 | | |
| | 6 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | | 22 |
| V | | 1 | 0 | 1 | 0 | 1 | 1 | 0 | | |
| | 7 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | | 23 |
| W | | 1 | 0 | 1 | 0 | 1 | 1 | 1 | | |
| | 8 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | | 24 |
| X | | 1 | 0 | 1 | 1 | 0 | 0 | 0 | | |
| | 9 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | | 25 |
| Y | | 1 | 0 | 1 | 1 | 0 | 0 | 1 | | |
| | : | 0 | 1 | 1 | 1 | 0 | 1 | 0 |  | 26 |
| Z | | 1 | 0 | 1 | 1 | 0 | 1 | 0 | | |
| | ; | 0 | 1 | 1 | 1 | 0 | 1 | 1 | | 27 |
| [ | | 1 | 0 | 1 | 1 | 0 | 1 | 1 | | |
| | < | 0 | 1 | 1 | 1 | 1 | 0 | 0 | | 28 |
| \ | | 1 | 0 | 1 | 1 | 1 | 0 | 0 | | |
| | = | 0 | 1 | 1 | 1 | 1 | 0 | 1 | | 29 |
| ] | | 1 | 0 | 1 | 1 | 1 | 0 | 1 | | |
| | > | 0 | 1 | 1 | 1 | 1 | 1 | 0 | | 30 |
| ^ | | 1 | 0 | 1 | 1 | 1 | 1 | 0 | | |
| NONE | | ILLEGAL | | | | | | | NONE | 31 |

Table 3.9 - Bus Operation Sequence

| | HANDSHAKE LINES | BUS LINES | DATA LINES | MEANING OR FUNCTION |
|---|---|---|---|---|
| 1 | | REN Lo | | Arms bus peripherals to go to remote mode. |
| 2 | | IFC | | Stops activity on the bus. |
| 3 | | ATN Lo | | Signifies that data byte will be a "Bus Message". |
| 4 | NRFD Hi | | | DMM says ready for data. |
| 5 | | | ? | UNL (Unlisten) message (ASCII character ?) on data bus by controller means "all bus peripherals unlisten". |
| 6 | DAV Lo | | | Controller says data on bus is valid. |
| 7 | NRFD Lo | | | DMM says its not ready for new data; do not change data lines while DMM is accepting data. |
| 8 | | | | DMM reads data lines. |
| 9 | NDAC Hi | | | DMM says it has read data. |
| 10 | DAV Hi | | ? | Controller says data no longer valid. |
| 11 | NDAC Lo | | | DMM removes data accepted flag. |
| 12 | NRFD Hi | | | DMM says it's ready for next data byte. |
| 13 | | | | Controller removes or changes data on bus. |
| 14 | | | U | "I talk", controller becomes talker (HP9825 talker address). |
| 15 | | | " | "You listen", addressed peripheral becomes listener (In this case it is the DMM set to decimal address 02; see table 3.9). |
| 16 | | ATN Hi | | Signifies that data byte will be a "Device Dependent Message" as opposed to an "Interface Message". |
| 17 | | | F | Function |
| 18 | | | 1 | DC Volts |
| 19 | | | R | Range |
| 20 | | | 5 | 10 Volts |
| 21 | | | T | Trigger |
| 22 | | | 1 | Continuous |
| 23 | | | CR | End of transmission by HP9825. |
| 24 | | | LF | |
| 25 | | ATN Lo | | Byte to follow is a Bus Message. |
| 26 | | | ? | UNL (unlisten) bus message. |
| 27 | | | B | "You talk", DMM talk address (02). |
| 28 | | | 5 | "I listen", HP9825 listen address. |
| 29 | | ATN Hi | | Message to be transmitted by DVM is Data. |
| 30 | | | + | Measurement data transmitted by DMM |
| 31 | | | 1 | |
| 32 | | | . | |
| 33 | | | 0 | |
| 34 | | | 2 | |
| 35 | | | 5 | |
| 36 | | | 4 | |
| 37 | | | 6 | |
| 38 | | | E | Exponent Indicator means X $10^{01}$ |
| 39 | | | + | Sign of exponent. |
| 40 | | | 0 | Exponent. Here it indicates $10^{10}$ |
| 41 | | | 1 | |
| 42 | | | CR | End of data message. |
| 43 | | | LF | |

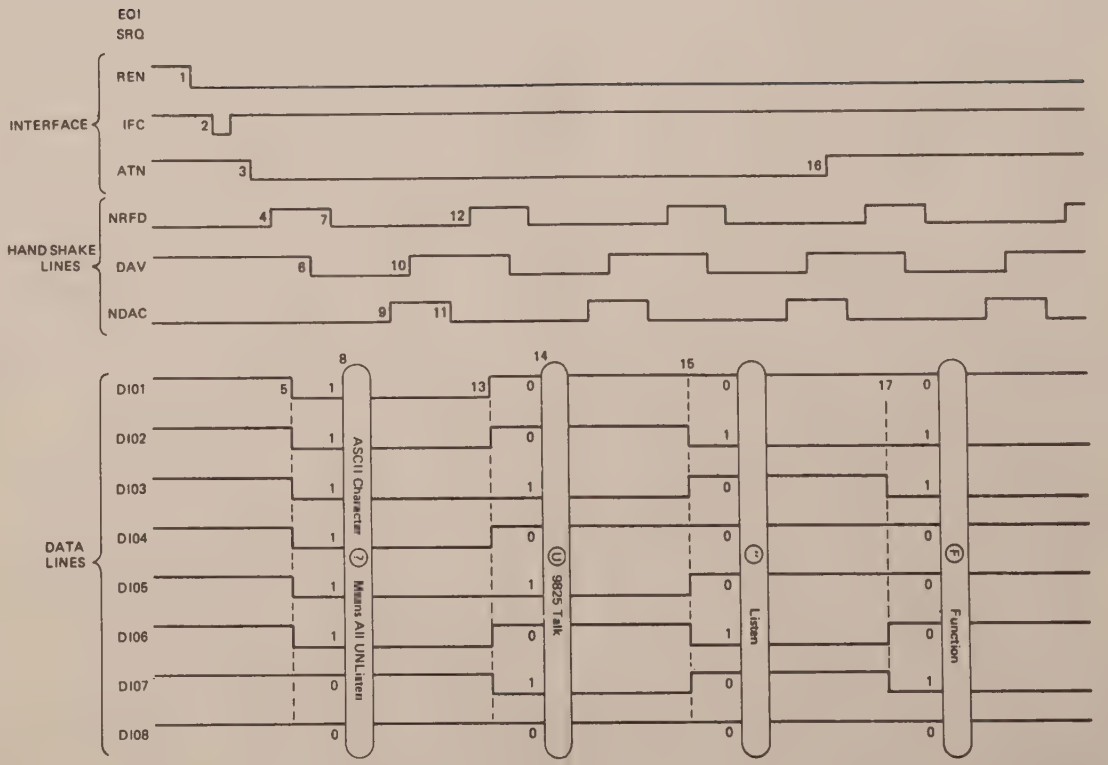



*Figure 3.19 - Interface Timing*

3.5.6.11 Having transmitted the program string of device dependent messages to the DMM, the controller then sets the ATN line low which indicates that the characters to follow in lines 26 through 28 are bus messages. These bus messages change the talker/listener relationship of the controller and DMM; the DMM is made a talker and the controller becomes a listener.

3.5.6.12 Lines 30 through 43 illustrate the sequence of the transmission of data by the DMM. The handshake sequence is the same when the DMM is transmitting data as that outlined in lines 1 through 13 of the table, except that the DMM is controlling the handshake lines.

3.5.6.13 Upon completion of the data transmission, the DMM transmits a carriage return (CR) and line feed (LF) to indicate the end of the data transmission. Refer to Table 3.10 for the GPIB programming requirements.

**Table 3.10 - GPIB Programming Requirements**

1. Character Code: 7 bit ASCII, upper or lower case.
2. All program strings transmitted to the DMM should end in a terminating character. Acceptable terminators are:
   - A. CR - Carriage Return
   - B. LF - Line Feed
   - C. EOI - This GPIB message EOI, true during transfer of the last byte of a string.
   - D. X - ASCII letter.
3. Programming numerical constant over the GPIB
   The following units are assumed when programming numerical constants over the GPIB:
   Volts
   Kohms,
   Hours • Minutes Seconds

### 3.5.7 Interface Message Repertoire.

3.5.7.1 The DMM is equipped with a standard GPIB interface which conforms to the specifications contained in IEEE-488-1978. The specification includes the definition of multi-line interface messages and this definition divides the messages into two groups; the primary command group and the secondary command group. The DMM includes none of the secondary command group in its interface message repertoire.

3.5.7.2 The primary command group of interface messages is further broken down into four lower categories: (1) the listen address group, (2) the talk address group, (3) the universal command group and (4) the addressed command group. The DMM is designed to include in its interface message repertoire 31 listen addresses and 31 talk addresses. The listen and talk addresses to which the DMM may be set are listed in Table 3.8.

3.5.7.3 The interface messages to which the DMM is designed to respond are listed in Table 3.11 along with their decimal equivalents, hex equivalents, meanings and data line codes. The function of the DMM in response to each of these commands is described in the following paragraphs.

3.5.7.4 GO TO LOCAL (GTL).

3.5.7.4.1 As shown in Table 3.11, the GTL command means go to local and the decimal and hex equivalent are both 01. Upon receipt of this interface message, the DMM, if previously programmed for remote, will return to its local operational state. This means that the instrument will then perform the function according to the settings of the front panel controls on the instrument until such time as it returns to remote control.

3.5.7.5 SELECTED DEVICE CLEAR (SDC).

3.5.7.5.1 Upon receipt of the SDC command, the DMM will go to the home state. The decimal and hex equivalent are both 04. The SDC message has the same effect as transmitting the GPIB program code 'Z' to the DMM.

3.5.7.6 GROUP EXECUTE TRIGGER (GET).

3.5.7.6.1 As shown in Table 3.11, the decimal and hex equivalents of the GET command are both 08. Upon receipt of the GET interface message, the DMM will trigger a reading if it had previously been placed in the HOLD mode. The group execute trigger command is used to trigger the simultaneous execution of a number of functions by a number of bus members at the same time. To use this command, one or more bus members are programmed to perform a function on receiving the GET interface message. Subsequently, the controller will transmit the GET command and all bus members previously programmed will begin execution on receipt of the command.

3.5.7.7 LOCAL LOCK OUT (LLO).

3.5.7.7.1 The DMM may be brought back into local control by pressing the "Local" key on the keyboard. If, however, the DMM receives an LLO (Hex 11 or decimal 17) command while in remote operation, it may not be brought back into local control through keyboard operation.

3.5.7.8 DEVICE CLEAR (DCL).

3.5.7.8.1 The decimal equivalent of the DCL command (as shown in Table 3.11) is 20, and the hex equivalent is 14. This command is identical in operation to the SDC command except that the DMM need not be a listener in order to respond to DCL. When this command is transmitted on the bus, all devices on the bus which respond to the DCL will clear. The DCL message has the same effect on the 5004 as transmitting the GPIB program code 'Z'.

3.5.7.9 SERIAL POLL ENABLE (SPE).

3.5.7.9.1 As shown in Table 3.11, the decimal equivalent of this interface command is 24; the hex equivalent is 18. The function of this command is to notify all bus members that they should output their serial poll status if made into a talker. Thus, when a bus member has transmitted a service request (SRQ), the bus controller can transmit the serial poll enable command, command each bus member to transmit its status byte by sequentially making each bus member a talker and thus identify the bus member requesting attention. Upon receipt of the DMM's talk address plus the SPE interface message, the DMM immediately prepares a status byte for transmission to the controller. If the DMM has previously transmitted an SRQ, it will set bit 7 of the status byte to 1. The serial poll allows a bus member to set the service request line to the 1 state, thus indicating to the controller that it wants attention. The controller may then sequentially interrogate each bus member to determine which one has requested service and the purpose of the request. The meanings of the bits in the status bytes are shown in Figure 3.20 and listed below:

a) Requested Service (DIO7). This bit indicates whether the DMM caused the SRQ (service request) line to be driven to the 'true' state; thus the controller can determine if the DMM is requesting service.

b) Abnormal Condition (DIO6). If true, this bit indicates the presence of an illegal or abnormal condition in the DMM, and is always in the same logical state as the DIO4 bit (see below).

c) Signal Integrate (DIO5). This bit is true during the time that the input (or external reference) signal is being measured by the DMM. In measurement systems where high throughput is important, this can be sampled by the controller to determine the earliest moment that the DMM's input signal can be changed, thus allowing multiple input signals to be measured in rapid succession. Note however that if the DMM is programmed to AUTO range, the Signal Integrate bit will go true multiple times as the DMM upranges or downranges.

d) Error Number Available (DIO4). This bit, which tracks bit DIO6 exactly, indicates that the DMM's Error Message register has been updated with a new error message. The error message can be retrieved

**Table 3.11 - Interface Messages Used With Model 5004 DMM**

| Message | Meaning | HEX CODE | Decimal Equiv. | DATA LINE CODE | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| GTL | Go To Local | 01 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 |
| SDC * | Selected Device Clear | 04 | 4 | 0 | 0 | 0 | 0 | 1 | 0 | 0 |
| GET * | Group Execute Trigger | 08 | 8 | 0 | 0 | 0 | 1 | 0 | 0 | 0 |
| LLO | Local Lock Out | 11 | 17 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| DCL | Device Clear | 14 | 20 | 0 | 0 | 1 | 0 | 1 | 0 | 0 |
| SPE | Serial Poll Enable | 18 | 24 | 0 | 0 | 1 | 1 | 0 | 0 | 0 |
| SPD | Serial Poll Disable | 19 | 25 | 0 | 0 | 1 | 1 | 0 | 0 | 1 |
| UNL | Unlisten | 3F | 63 | 0 | 1 | 1 | 1 | 1 | 1 | 1 |
| UNT | Untalk | 5F | 95 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |

*Instrument will ignore message unless it is a listener

over the bus by use of the 'Y' command which is described in Section 3.5.20.

e) Data Ready (DIO1). This bit is affected by the completion of a reading as well as the most recently programmed Interrupt Command (D0-D3). Section 3.5.22 gives more details on the Interrupt (D0-D3) commands.

3.5.7.10 SERIAL POLL DISABLE (SPD).

3.5.7.10.1 As shown in Table 3.11 the decimal equivalent to the SPD command is 25; the hex equivalent is 19. The function of this command is to return the bus members to their original states after the serial poll transaction has been completed.

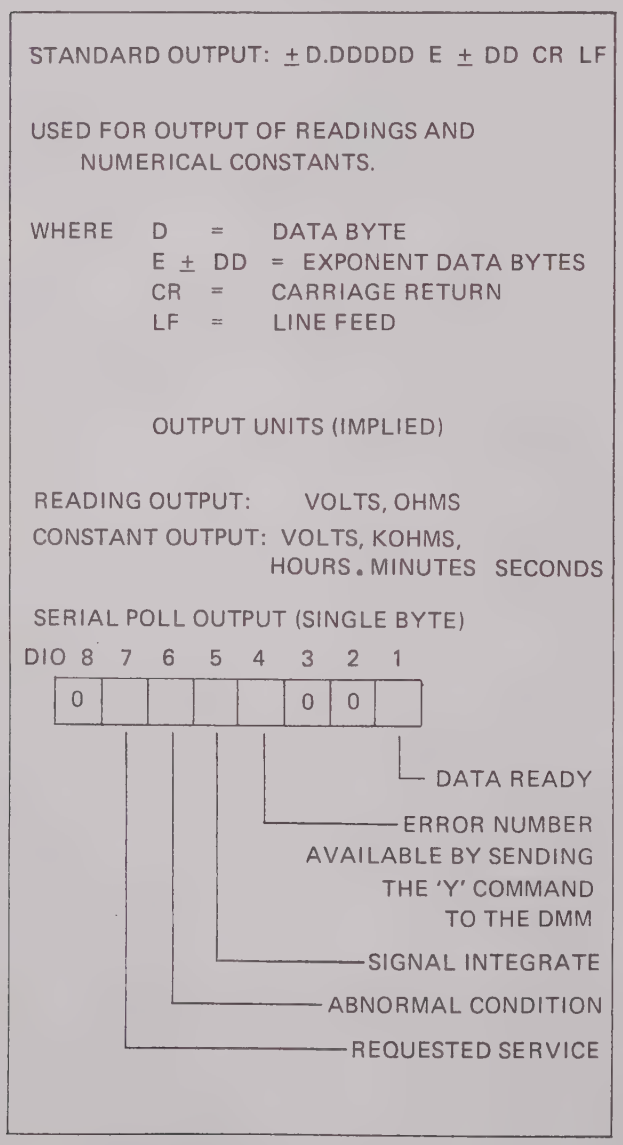

STANDARD OUTPUT: ± D.DDDDD E ± DD CR LF
USED FOR OUTPUT OF READINGS AND NUMERICAL CONSTANTS.
WHERE D = DATA BYTE
E ± DD = EXPONENT DATA BYTES
CR = CARRIAGE RETURN
LF = LINE FEED
OUTPUT UNITS (IMPLIED)
READING OUTPUT: VOLTS, OHMS
CONSTANT OUTPUT: VOLTS, KOHMS, HOURS . MINUTES SECONDS
SERIAL POLL OUTPUT (SINGLE BYTE)
DIO 8 7 6 5 4 3 2 1
0 0 0
DATA READY
ERROR NUMBER AVAILABLE BY SENDING THE 'Y' COMMAND TO THE DMM
SIGNAL INTEGRATE
ABNORMAL CONDITION
REQUESTED SERVICE

*Figure 3.20 - GPIB Output Formats*

3.5.7.11 UNLISTEN (UNL).

3.5.7.11.1 As shown in Table 3.11 the decimal equivalent of this command is 63; the hex equivalent is 3F. This command is also a universal interface message understood by all members of the bus as a command to go to the unlisten state. When this command is transmitted, all bus members previously in the listen state will return to the unlisten state.

### 3.5.8 Device Dependent Messages.

3.5.8.1 The messages which control the operation of the DMM when in system operation are referred to as device dependent messages. These messages listed in Table 3.12 are simply combinations of ASCII characters which the instrument recognizes as specific instructions. To program the instrument for a specific operation, the operator programs the controller to transmit a sequence of these messages (referred to as a program string). The program string is variable in length and has no fixed format. Individual commands may be transmitted in any order and require no delimiters or spacing for the instrument to understand. A terminator character(s) should be sent as the last character in each program string. Acceptable terminators are CR (Carriage Return), LF (Line Feed), the GPIB message EOI in conjunction with the last byte of the string, also ASCII x lower case or X uppercase, or any combination of these. Most controllers will add terminator to the program string automatically. Alphabetic characters may be either upper or lower case. Table 3.10 summarizes the GPIB programming requirements.

3.5.8.2 The device dependent messages are listed in Table 3.12 along with the DMM operation and any special notes that apply. The device dependent messages applicable to the DMM are divided into subcategories such as Function Commands and Range Commands. In general, the various commands cause the instrument to perform the same functions as the front panel controls. There are special cases however, where there are extra functions available under remote control which are not available in the bench operation mode. Further, there are some special situations requiring special attention to the operation sequence used with the DMM.

3.5.8.3 To assemble a program string, first list the requirements of the program, and then select the appropriate program codes from Table 3.12. Table 3.9 shows a program string listing for a typical measurement procedure.

### 3.5.9 GPIB STORE and RECALL Commands.

3.5.9.1 Two main buffers are used during GPIB STORE/RECALL Commands. These commands cause readings and numerical constants to be moved from one memory location to another inside the DMM. To understand how these commands operate, refer to Figure 3.21. The output buffer

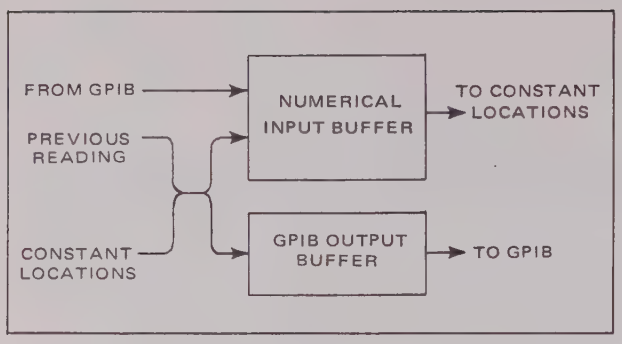



*Figure 3.21 - GPIB Numerical Buffers*

holds the ASCII characters which are waiting to be transmitted to the controller. The input buffer has two uses. During the entry of numerical constants from the bus, the input buffer is used as the holding register. Also, the input buffer is used to hold the number which was most recently transferred to the output buffer.

3.5.9.2 GPIB Store Commands cause the contents of the Numerical Input Buffer to be transferred to a constant location in the DMM's memory as follows:

a) N2, store as a NULL constant.

b) P2, store as a Percent constant.

c) L6, store as a LAH cycle constant, 'C'.

d) S2-S7, store as TIME constants.

Either the previous reading or a GPIB entered constant can be stored. For instance, if a reading is completed and then an N2 command is sent to the DMM, the reading will be stored as the NULL constant. If any of the following command strings are transmitted to the DMM:

–2.5e-3 N2

–2500000 E-9 N2

–000000000.0025 N2

–.000000000025E+08 N2

then –.0025 will be stored as the Null Constant. .

3.5.9.3 GPIB RECALL Commands cause numerical constant(s) to be copied into the Numerical Input and GPIB Output Buffers for transmission to the controller as follows.

a) N3, transmit NULL Constant.

b) P3, transmit Percent Constant.

c) L7, transmit 5 LAH constants.

d) S8, transmit 6 TIME constants.

e) C1, transmit contents of Data Buffer.

3.5.9.4 The following points should be kept in mind when using GPIB recall commands:

a) The outputting of the above-mentioned data and constants takes priority over outputting of readings to the bus. In other words, readings will be displayed but not saved for GPIB output if the GPIB Output buffer is occupied by an out-going constant.

b) When the outputting of constant(s) is completed, the DMM will automatically resort to outputting readings.

c) Output Commands are not "stored" internally, therefore if more than one is sent, only the most recently transmitted output command will be honored.

3.5.9.5 The following apply only when outputting multiple constants (GPIB commands L7, S8, C1).

a) In keeping with the IEC and IEEE recommendations, multiple constants are separated by commas (,) and a terminator(s) CR LF appears after the last constant. This may require special programming on some controllers which do not meet IEC/IEEE recommendations.

b) As each constant is outputted, the DMM aborts any reading presently in progress and will re-start the reading. This may lower the read rate for a split second as the constants are output.

Table 3.12 - Model 5004 Device Dependent Program Code

INITIALIZE COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Initialize | Z | Same as G0T1N0P0L0S0 |

FUNCTION COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| DC Volts | F1 | |
| AC Volts | F2 | |
| Ohms | F3 | |
| Ohms | F4 | |

RANGE COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| AUTO Range | R0 | |
| .1V, .1KΩ | R3 | |
| 1V, 1KΩ | R4 | |
| 10V, 10KΩ | R5 | |
| 100V, 100KΩ | R6 | |
| 1000V, 1000KΩ | R7 | |
| 10,000KΩ | R8 | |

TRIGGER COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Trigger Immediate | T0 | Normally used in conjunction with T3. |
| Internal Trigger | T1 | Causes continuous readings. |
| External Trigger | T2 | Waits for trigger from rear panel BNC. |
| Hold/Manual | T3 | Waits for trigger from GPIB or from keyboard. |
| External Trigger with Timeouts | T4 | Same as $T_2$ and $T_3$, except that an internal time delay is inserted to allow for analog settling times. |
| Hold/Manual with Timeouts | T5 | |

**Table 3.12 - Model 5004 Device Dependent Program Code continued**

LOW/HIGH RESOLUTION COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| 4 1/2 digit display | I1 | |
| 5 1/2 digit display | I2<br>I3 | |

FILTER COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Filter Out | J0 | |
| Filter In | J1 | Selects the 3-pole active filter. |

INTERRUPT COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| No SRQ when Reading is Ready | D0 | |
| SRQ when Reading is Ready | D1 | |
| SRQ if Reading* is < 0 | D2 | |
| SRQ if Reading* is ≥ 0 | D3 | |

*Reading after being modified by Null, % and LAH.

FRONT/REAR INPUT COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Front Input | V0 | Measurements taken from the front input terminals. |
| Rear Input | V1 | Measurements taken from the rear input terminals. |

**Table 3.12 - Model 5004 Device Dependent Program Code continued**

COMMAND STRING TERMINATOR (OPTIONAL)

| Operation | Code | Special Notes |
|---|---|---|
| Terminator | X | Use is required only when the 5004 is being programmed from a controller which does not terminate the program string with a CR, LF, or EOI. |

ERROR OUTPUT COMMAND

| Operation | Program Code | Special Notes |
|---|---|---|
| Error Output | Y | Output most recent error number. |

DIGITAL ZERO COMMAND

| Operation | Program Code | Special Notes |
|---|---|---|
| Ignored | K0 | |
| Ignored | K1 | |
| Zero Command | K2 | DC Function 0.1V range (F1R3), must have been previously selected, and a short must be supplied across the input terminals. |

CALIBRATION COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Decrease offset, this range | K3 | These commands have no effect unless the front panel calibration button is depressed, or shorted as described in maintenance section 5.1.6. |
| Nominal offset, this range | K4 | |
| Increase offset, this range | K5 | |
| Decrease scale, this range | K6 | |
| Nominal scale, this range | K7 | |
| Increase scale, this range | K8 | |
| Calculate and Store Checksum | K9 | |

**Table 3.12 - Model 5004 Device Dependent Program Code continued**

NULL COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Disable Null | N0 | |
| Enable Null | N1 | Subtracts null constant from reading. |
| Store as Null | N2 | Stores previous reading or entered constant as null constant. |
| Transmit Null | N3 | Output null constant to GPIB. |

PERCENT COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Disable % equation | P0 | |
| Enable % equation | P1 | |
| Store as % constant | P2 | |
| Transmit % constant | P3 | |

LOW AVG HIGH (LAH)

| Operation | Program Code | Special Notes |
|---|---|---|
| Disable LAH | L0 | |
| Enable and display/ output reading | L1 | |
| Enable and display/ output Low | L2 | |
| Enable and display/ output Avg | L3 | |
| Enable and display/ output High | L4 | |
| Enable and display/ output # rdgs so far | L5 | |
| Store as number to be averaged | L6 | |
| Transmit constants: | L7 | Outputs to GPIB: Low, Avg, High, #rdgs (n) , Average cycle constant (c) |

**Table 3.12 - Model 5004 Device Dependent Program Code continued**

PROGRAM BUFFER STORE COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Store to Pgm 0 | A0 | Store present machine setting to program buffer location 0. |
| Store to Pgm 1 | A1 | Store present machine setting to program buffer location 1. |
| Store to Pgm 2 | A2 | Store present machine setting to program buffer location 2. |
| Store to Pgm 3 | A3 | Store present machine setting to program buffer location 3. |
| Store to Pgm 4 | A4 | Store present machine setting to program buffer location 4. |
| Store to Pgm 5 | A5 | Store present machine setting to program buffer location 5. |
| Store to Pgm 6 | A6 | Store present machine setting to program buffer location 6. |
| Store to Pgm 7 | A7 | Store present machine setting to program buffer location 7. |
| Store to Pgm 8 | A8 | Store present machine setting to program buffer location 8. |
| Store to Pgm 9 | A9 | Store present machine setting to program buffer location 9. |

PROGRAM BUFFER RECALL COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Recall Program 0 | B0 | Recall the machine setting previously stored at location 0. |
| Recall Program 1 | B1 | Recall the machine setting previously stored at location 1. |
| Recall Program 2 | B2 | Recall the machine setting previously stored at location 2. |
| Recall Program 3 | B3 | Recall the machine setting previously stored at location 3. |
| Recall Program 4 | B4 | Recall the machine setting previously stored at location 4. |
| Recall Program 5 | B5 | Recall the machine setting previously stored at location 5. |
| Recall Program 6 | B6 | Recall the machine setting previously stored at location 6. |
| Recall Program 7 | B7 | Recall the machine setting previously stored at location 7. |
| Recall Program 8 | B8 | Recall the machine setting previously stored at location 8. |
| Recall Program 9 | B9 | Recall the machine setting previously stored at location 9. |

DATA BUFFER COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| Clear Data Buffer | C0 | |
| Output Contents of Data Buffer to the GPIB | C1 | Outputs entire contents of data buffer |

**Table 3.12 - Model 5004 Device Dependent Program Code continued**

EXTERNAL REFERENCE FUNCTION COMMANDS (SOFTWARE RATIO)

| Operation | Program Code | Special Notes |
|---|---|---|
| Internal Reference | G0 | Disables Software Ratio. |
| DC Reference | G1 | Enable Software Ratio. |
| AC Reference | G2 | |
| Ohms Reference | G3 | |
| Ohms Reference | G4 | |

EXTERNAL REFERENCE RANGE COMMANDS

| Operation | Program Code | Special Notes |
|---|---|---|
| AUTO Range | Q0 | Returning the DMM to internal reference will not affect the external reference range setting. |
| .1V, .1KΩ | Q3 | |
| 1V, 1KΩ | Q4 | |
| 10V, 10KΩ | Q5 | |
| 100V, 100KΩ | Q6 | |
| 1000V, 1000KΩ | Q7 | |
| 10000KΩ | Q8 | |

TIME

| Operation | Program Code | Special Notes |
|---|---|---|
| Disable Time | S0 | DMM should be in HOLD mode (T3-Command) when TIME function is enabled. |
| Enable Time function | S1 | |
| Store as start Time | S2 | |
| Store as stop Time | S3 | |
| Store as interval | S4 | |
| Store as subinterval | S5 | |
| Store as N | S6 | |
| Store as present Time | S7 | |
| Output time constants to the GPIB | S8 | Output Present time, N, Subinterval, Interval, Stop time, and Start time. |

### 3.5.10 Initialize Command.

3.5.10.1 The program code 'Z' is normally used by the controller to place the DMM into a known state. This program code is equivalent to the following string: G0T1N0.

G0 - Internal reference
T1 - Internal trigger
N0 - Disable NULL
P0 - Disable percent
L0 - Disable LAH
S0 - Disable Time

### 3.5.11 Function Commands.

3.5.11.1 Function commands are available to program the instrument to perform any operation which may be commanded through use of front panel keyboard controls. Note that in Table 3.9 the DMM Operation column lists the functions available on the instrument and that the Program Code column shows the ASCII characters required to program the instrument for each of these functions. To program a function the controller need only transmit the ASCII characters required for the desired function (eg: to program the measurement function DC volts, the controller simply transmits the two ASCII characters F and 1 over the bus to the DMM).

### 3.5.12 Range Commands.

3.5.12.1 Seven individual range commands are available to the controller; one to command the autorange and six additional commands for selecting specific ranges for the instrument. Note that the commands R3 through R7 all serve dual purposes; they command ranges for voltage measurements and for resistance measurements.

### 3.5.13 Trigger.

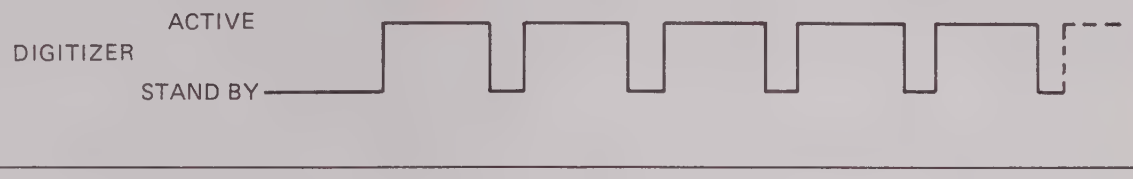
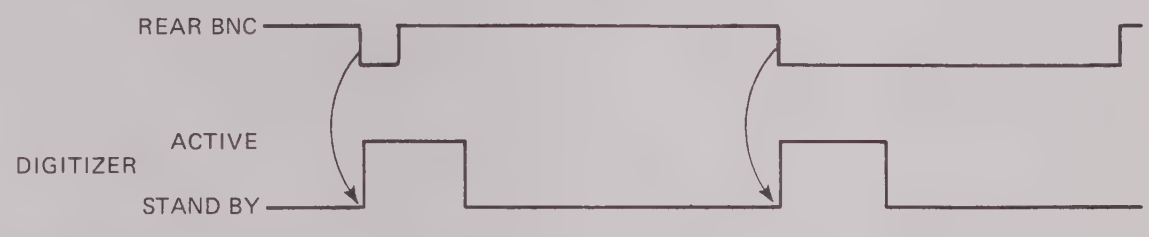
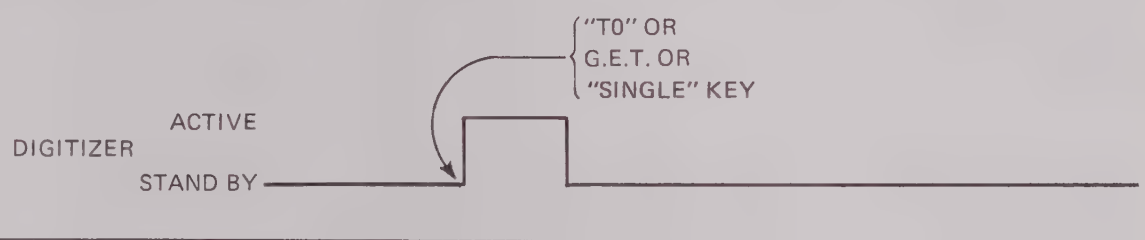
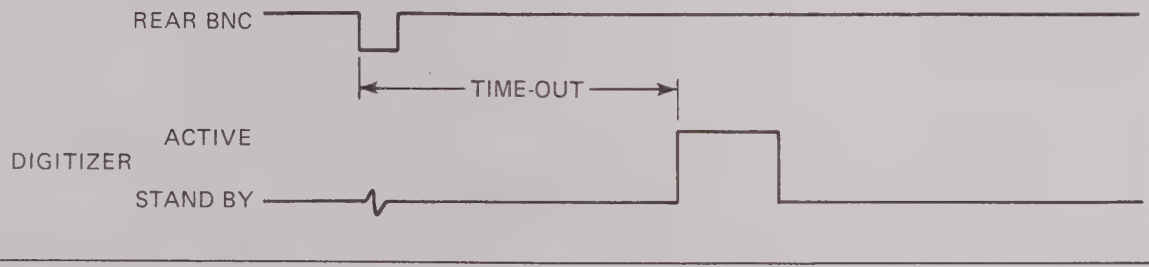
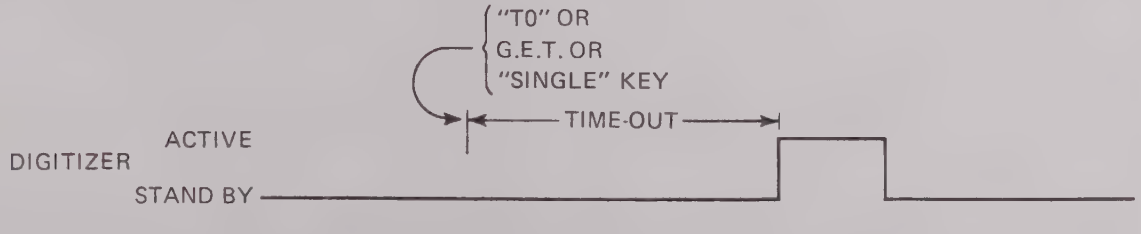
3.5.13.1 Trigger commands T0 through T5 control the beginning of a measurement cycle. When the T1 command is transmitted, the instrument operates on the internal trigger on its normal measurement timing cycle (see Figure 3.22). When the T2 command is transmitted, the instrument must be triggered by an external signal inputted through a BNC connector on the rear panel of the instrument. When the T3 command is transmitted, the instrument is put in the "Hold" state and will stay there until it is triggered either from the front panel or from the GPIB. Trigger commands from the GPIB can be either a T0 command or a Group Execute Trigger. Trigger commands are given from the keyboard by pressing 'Track' or 'Single' when the DMM is in local control. Upon receipt of the T4 program code the instrument goes into the External trigger mode and must be triggered by an external signal connected to the rear panel BNC connector. After being triggered via the rear panel BNC, the DMM executes a timeout which allows time for analog signals to settle. The timeout will vary, depending upon which functions and ranges are selected, before triggering a single reading. When program code T5 is transmitted, the instrument goes into the "Hold" mode described above except that its measurement cycle is again affected by the timeouts applicable to each function and range. For a complete description of 'TIME-OUTS' see paragraph 3.6.

### 3.5.14 HI-LO Resolution Commands.

3.5.14.1 The measurement accuracy of the DMM is directly proportional to the signal integration time (ie: the longer the integration time, the more accurate the measurement). If the measurement time is available, more accuracy may be obtained by programming the longer integration period. In situations where speed is required, the shorter integration time may be programmed at some sacrifice in measurement accuracy. The program codes I1, I2 and I3 select the resolution, the accuracy and the reading rate. Code I1 enables the 4 1/2 digit display which generates higher speed at the sacrifice of accuracy. Codes I2 and I3 develop greater accuracy at reduced speed.

### 3.5.15 Null Commands.

3.4.15.1 Program codes N0 through N3 call for the Null functions. The N1 program code enables the Null function. Upon receipt of N1 from the interface, a flag is set in

| TRIGGER COMMAND | TYPICAL WAVEFORM |
|---|---|
| T1 |  |
| T2 |  |
| T3 |  |
| T4 |  |
| T5 |  |



NOTE: G.E.T. IS AN ABBREVIATION FOR THE GPIB COMMAND "GROUP EXECUTE TRIGGER"

*Figure 3.22 - Trigger Command Measurement Timing*

memory which signals the Computer to subtract the Null constant from future readings. The N2 program code allows for the storage of Null constants. Upon receipt of the N2 command, the previous reading or a constant enter via the GPIB is stored into memory for use as the Null constant. The N3 program code causes the DMM to transmit the Null constant to the controller.

3.5.15.2 The N1N2 program string accomplishes the same operation as selection of the "Null" key on the keyboard. Program code N0 disables the Null function but does not change the Null constant.

### 3.5.16 Interrupt Commands.

3.5.16.1 Commands may be transmitted by the controller to instruct the DMM to send an SRQ (Service Request) signal over the GPIB. When the SRQ occurs, the controller can read the DMM's Serial Poll status byte to determine the cause of the SRQ. Figure 3.20 identifies the Data Ready bit in the status byte which will set to 1 if the SRQ was sent to inform the controller that a reading is ready for transmission over the bus.

3.5.16.2 The Interrupt Commands D0-D3 determine what type of readings will cause the SRQ and Data Ready messages to become true, as shown in Table 3.13 and explained below. If the D0 command is programmed, the DMM will not send an SRQ or set the Data Ready bit true when a reading becomes available for GPIB output. If the D1 command is programmed, the DMM will always send an SRQ and set the Data Ready bit in the status byte.

**Table 3.13 - Effects of D0 Thru D3 Interrupt Commands**

| Most Recently Transmitted 'D' Command | Newly Completed DMM Reading (after Null, %, etc.) | Service Request SRQ | Serial Poll Status Byte | |
|---|---|---|---|---|
| | | | Requested Service Bit (DIO7) | Data Ready Bit (DIO1) |
| D0 | + or – polarity | False (1) | 0 (2) | 0 |
| D1 | + or – polarity | True | 1 | 1 |
| D2 | – polarity | True | 1 | 1 |
| | + polarity | False (1) | 0 (2) | 0 |
| D3 | + polarity | True | 1 | 1 |
| | – polarity | False (1) | 0 (2) | 0 |

(1) May be driven True by another bus member.

(2) Usually zero, but may be set to one for reason other than Data Ready.
See Section 3.5.7.9 for further explanation.

3.5.16.3 If the D2 command is programmed, an SRQ will be sent and the Data Ready bit will be set, but only if the reading (after Null, %, etc.) has a negative polarity sign (number is less than zero). If the D3 command is programmed, an SRQ will be sent and the Data Ready bit will be set, but only if the reading (after Null, %, etc.) has a positive polarity sign (number is greater than or equal to zero).

3.5.16.4 The D2 and D3 commands can be used to notify the controller that the DMM's input signal has increased or decreased across an important boundary. For instance, if +2.0 is programmed as the Null constant and Null is enabled, the D2 or D3 command can be used to notify the controller that the input signal has moved across +2 volts.

3.5.16.5 The following should be kept in mind when using the D1, D2 or D3 commands:

a) The SRQ line and Data Ready bits can be reset to their home state in the following ways:

1) Both are reset whenever the DMM is reprogrammed over the bus.

2) Both are reset by making the DMM a talker and accepting the entire reading from the DMM over the bus.

e) SRQ will be reset whenever the controller reads the DMM's serial poll status byte.

b) If the DMM is programmed with the D2 or D3 command, the SRQ line and Data Ready bit will remain true even though the most recent reading may not be the proper polarity to cause them to be set true. For example, if the D2 command is programmed and then a negative reading followed by a positive reading is taken, the SRQ line and Data Ready bits will remain set, assuming of course, that none of the procedures listed in a) take place.

### 3.5.17 Filter Commands.

3.5.17.1 Control of the active filter in the remote mode is the same as manual control of the filter except that the controller transmits the program code commands J0 and J1 (as shown in Table 3.12).

### 3.5.18 Digital Zero Command.

3.5.18.1 The code F1R3 must precede the Digital Zero command code K2 to enable the Digital Zero command.

Furthermore, the HI-LO INPUT terminals on the front or rear panel of the DMM must be shorted.

### 3.5.19 Command String Terminator.

3.5.19.1 The terminator code "X" permits the controller to terminate the program string when other terminating codes were not included in the string: typical terminators are CR, LF, or EOI. Most modern controllers will append a terminator to program strings automatically, making the use of 'X' program code unnecessary.

### 3.5.20 Error Output Command.

3.5.20.1 When a programming error or operational error is discovered by the DMM when in remote, an SRQ is sent to the controller. Upon receiving the SRQ, the controller should read the DMM's status byte to determine why the SRQ was sent. If the status byte contains '1' in the DIO-4 position (see Figure 3.20) then an error has occured and an error number can be transmitted to the controller. To obtain this error message number, the controller first sends the program code 'Y' (why) to the DMM and then reads the error message number from the DMM. Table 3.6 can then be used to determine the nature of the problem.

### 3.5.21 Calibration Commands.

3.5.21.2 If a CAL LAB is handling more than ten μ5000 series voltmeters, it may be advantageous to automate the calibration of the DMM's. To do this, the front panel "CAL" switch is shorted on the main PCB and then commands K3 through K8 are transmitted to the DMM to modify Non-Volatile memory constants. After all other Cal commands have been completed, the K9 command should be transmitted to the DMM. When the calibration is completed, the short across the CAL switch "must" be removed. Refer to Section 5.3.4 for additional details.

### 3.5.22 Front/Rear Input Commands.

3.5.22.1 Program codes V0 and V1 select front or rear input terminals of the DMM. V0 enables measurements from the front input terminals and V1 enables measurements from the rear input terminals.

### 3.5.23 Time Commands.

3.5.23.1 Program Codes S0 through S8 address the DMM real-time clock as it is applied to readings in progress. The Start Time, Stop Time, Time Interval, Subinterval Time and number of readings per interval can be selected and stored.

### 3.5.24 Percent Commands.

3.5.24.1 The Percent Commands of P0 and P3 can enable or disable the % equation $\left(\frac{\text{READING-REFERENCE}}{\text{REFERENCE}}\right) X\ 100$ which is the percentage deviation of the input reading from a reference value. Storing as a % constant or transmitting as a % constant completes this message group.

### 3.5.25 LOW-AVERAGE-HIGH Commands (LAH).

3.5.25.1 The program codes L0 through L7 can disable or enable the LAH function or execute the LAH modes which are described in section 3.4.8. They store the number to be averaged or Transmit the LAH constants included in this group of device dependent messages.

### 3.5.26 Program Buffer Store Commands.

3.5.26.1 Up to 10 instruments settings can be stored with the program codes A0 through A9. Each code stores to one program number. The detail operation of the Program Buffer is presented in section 3.4.12.2.

### 3.5.27 Program Buffer Recall Commands.

3.5.27.1 The 10 instrument settings can be recalled with the program codes B0 through B9. The setting stored to a program number can be recalled in any sequence. The operation of the recall function of the program buffer is presented in section 3.4.12.2.

### 3.5.28 Data Buffer Commands.

3.5.28.1 The two program codes for Data Buffer can address the two buffer modes which are:

a) Clear the Data Buffer.

b) Recall previous readings from the Data Buffer to the GPIB. (See also section 3.5.9)

### 3.5.29 Software Ratio Commands (External Reference).

3.5.29.1 The Software Ratio Command is an Extended Software Capability feature of the DMM that allows the DMM to function as a ratiometer. This feature is not selectable from the keyboard, and no LED annunciation is provided on the front panel to indicate that the Software Ratio mode is selected. When in the Software Ratio mode, the

**Table 3.14 - Front/Rear and Software Ratio Codes**

| Most Recent GPIB Program Code | (RI) Annunciator Condition | Front Input Terminals | Rear Input Terminals | Ratio Displayed |
|---|---|---|---|---|
| V0 (Front Input terminals selected) | Off | Measurement Signal | Reference Signal | Ratio = Front / Rear |
| V1 (Rear Input terminals selected) | On | Reference Signal | Measurement Signal | Ratio = Rear / Front |

DMM reads the Measurement Signal, reads the External Reference Signal, then calculates

$$\text{Ratio} = \frac{\text{Measurement Signal}}{\text{External Reference Signal}}$$

3.5.29.2 The Measurement and Reference signals are connected to the DMM's front and rear input terminals. Table 3.14 indicates how the GPIB Front/Rear Commands V0 and V1 determine which Input terminals are used for Measurement Signal and Reference Signal connection.

3.5.29.3 Since the programming of the Reference Function/Range is completely independent of the Measurement Function/Range, over 200 types of Software Ratio can be programmed. A few examples are:

$$\frac{\text{DC 10V range}}{\text{Ohms 100K range}} \qquad \frac{\text{AC 1V range}}{\text{AC 1V range}}, \text{ and } \frac{\text{Ohms .1 range.}}{\text{DC 100 range}}$$

3.5.29.4 When in Software Ratio mode, the time to complete a reading can be calculated from Figure 3.25 or Figure 3.26, which, along with the GPIB throughput calculations in paragraph 3.7, supply the necessary information to calculate the time required to program, trigger, and transfer a reading back to the controller.

3.5.29.5 EXTERNAL REFERENCE FUNCTION COMMANDS.

3.5.29.5.1 External reference function commands are used to select the voltage reference used by the digital multimeter in making measurements. The controller may select the normal internal reference (ratio disabled) or an external ratio reference. Transmission of the G0 program code by the controller causes the DMM to use internal reference for all measurements. When using the instrument in the external reference mode, the reference is applied to the front panel or rear panel reference terminals, as shown in Table 3.14.

3.5.29.5.2 When using a DC external reference, the user first connects the signal and reference as described above and then transmits the program code G1. For AC external reference, the same hook up is made followed by a G2 command. For ohms external reference, either the G3 or G4 commands may be used.

3.5.29.6 EXTERNAL REFERENCE RANGE COMMANDS

3.5.29.6.1 There are six ranges for external reference signals applied to the Input connector of the DMM. These are listed in Table 3.12 under the Operation column heading. When using an external reference in remote mode, the controller must transmit the appropriate program code Q3 through Q8 to select the correct range. Q0 selects the reference auto-range function.

## 3.6 TIME-OUTS: A PRACTICAL TREATISE.

3.6.1 TIME-OUTS are variable delays which are inserted at the proper point in the measurement sequence in order to guarantee that the signal has settled sufficiently before a reading is taken.

3.6.2 Like many other Racal-Dana DMM's, the Model 5004 provides 2 types of time-outs. Together these time-outs reduce the burden on the GPIB programmer because most of the system timing problems involving insufficient

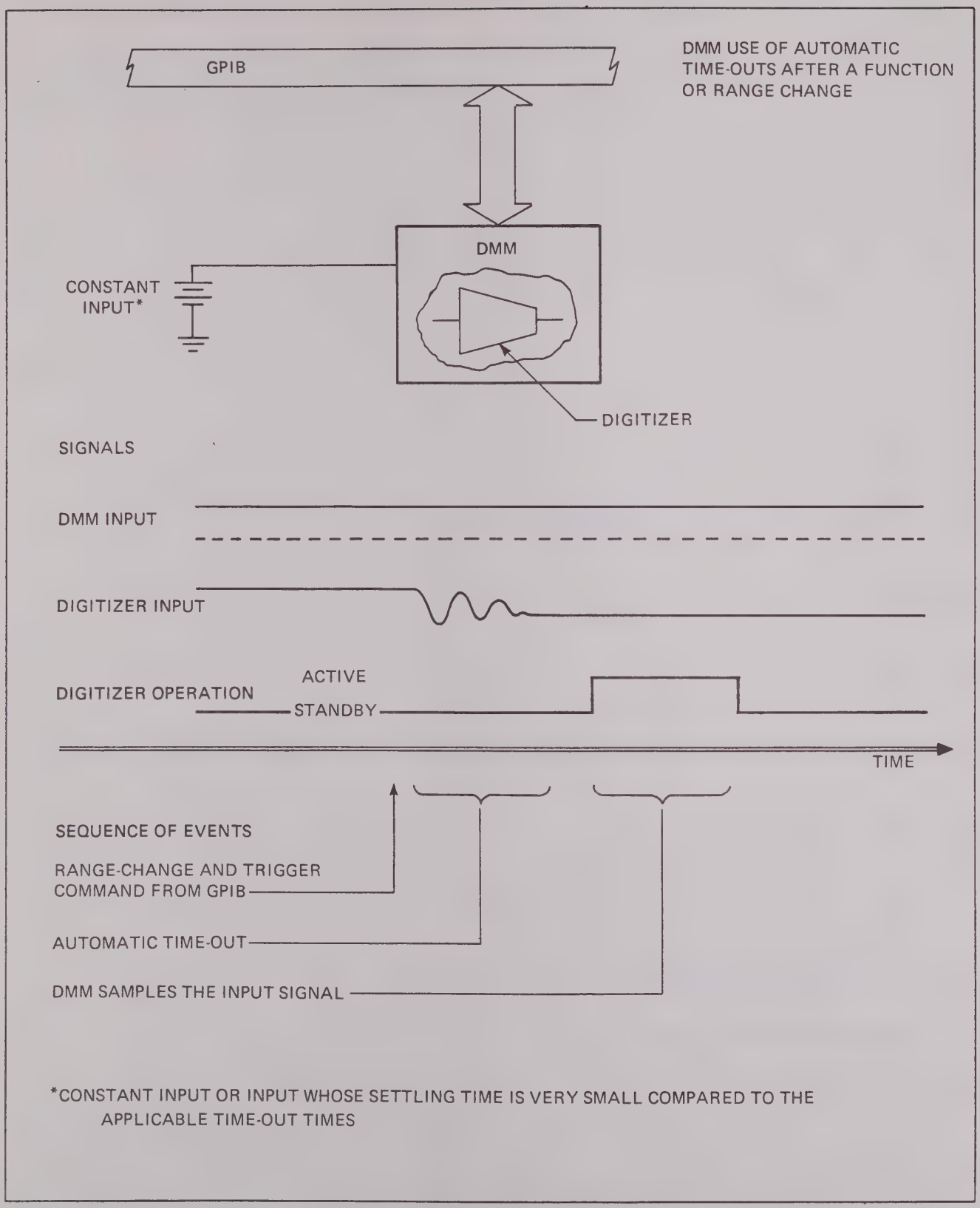



*Figure 3.23 - DMM Automatic Time-Out*

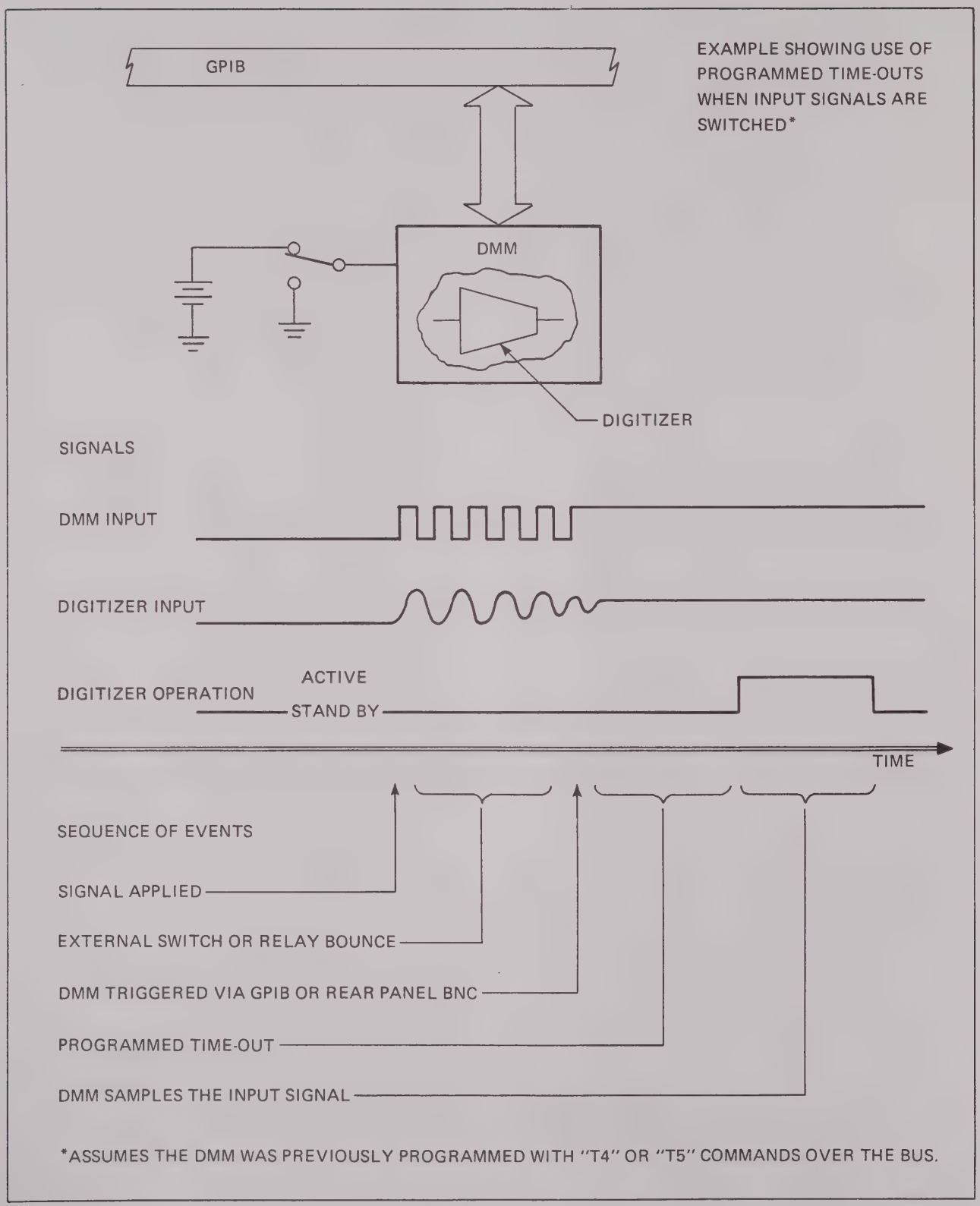



*Figure 3.24 - DMM Programmed Time-Out*

settling times and first reading errors are taken care of automatically inside the Model 5004. "First Reading Error" is an erroneous reading output by an instrument immediately following a function or range change.

**Table 3.15 - Time-Out Times**

| Function | Time-Outs | Digits Error | |
|---|---|---|---|
| | | 5 1/2 Mode | 4 1/2 Mode |
| DC | 30 mS | 10 | 1 |
| AC* | 400 mS | 100 | 10 |
| KΩ .1-1K | 40 mS | 10 | 1 |
| 10K | 300 mS | 10 | 1 |
| Any Function Plus Filter | 500 mS | 10 | 1 |

*Time-out will be insufficient if incoming signal has a DC level other than zero volts.

3.6.3 Table 3.15 lists the time-out times and also lists the remaining digits of error which are not compensated for by the time-outs.

3.6.4 When any DMM is being programmed and triggered over the GPIB, a typical chain of events may occur something like this:

1) Apply input signal to DMM.
2) Program DMM and trigger reading.
3) Take reading from DMM.

Figure 3.23 shows this sequence graphically and also shows how the DMM automatic timeout feature prevents it from outputting bad data after a function, range change, or other GPIB command. Notice in the figure that the input signal is assumed to have already settled before the sequence begins.

3.6.5 Another chain of events which commonly occurs is listed below. This situation is found more often when many inputs of the same type are being measured:

1) Apply input signal to DMM.
2) Trigger DMM (without changing function or range).
3) Take reading from DMM.

Figure 3.24 shows this sequence and also shows how the use of programmed time-outs (T4 and T5 commands) allow the programmer to pass the responsibility for settling time over to the DMM. Here again it is assumed that the input signal has already settled before the DMM is triggered, since it would be impossible for the DMM to compensate for an unknown settling time caused by conditions external to the DMM.

3.6.6 In the previous paragraphs it was mentioned how the DMM handled its own settling time problems in various ways, but no mention was made of how the programmer might deal with settling time problems which originate external to the DMM. When low impedance measurements are being made, the main cause of delay times external to the DMM occur either in the signal source or in the signal scanner. Unless compensated for, these delays can cause large measurement errors.

3.6.7 One way of dealing with this situation is to place a delay in the controller's software between the signal setup routines and the DMM trigger routines, thus guaranteeing that the signal has settled before the DMM is triggered. A complication arises because the required delay time may vary considerably depending upon which signal source function and range is selected, etc. In systems where test time is not critical, the programmer may decide to use the worst case required delay during all measurements.

3.6.8 If throughput is a consideration, the programmer may decide to use a variable delay which depends upon the selected signal source and scanner settings, but this approach may require intimate knowledge of the devices' internal workings or repeated experimentation. Recently another alternative has been made available in the form of smart signal sources and scanners which can control system timing to guarantee that the signal has settled before the next operation is allowed to proceed. One example of this class of smart scanners is the Racal-Dana Model 1200. When programmed to do so, it will hold off further GPIB activity until all of its relays have switched to their new positions and have ceased bouncing. In most cases this guarantees that the Model 1200's output signal has completely settled before the controller has a chance to trigger the measurement device.

## 3.7 GPIB THROUGHPUT CALCULATIONS: A PRACTICAL TREATISE.

3.7.1 This section which presents GPIB Throughput Calculations is included as an aid to systems designers who must determine how much time is required to program, trigger, and obtain a reading from the Model 5005 DMM when operated over the GPIB.

3.7.2 The HANDSHAKE TIMES listed in Table 3.16 are typical times required to handshake characters over the bus. These numbers can be used to estimate the bus time required

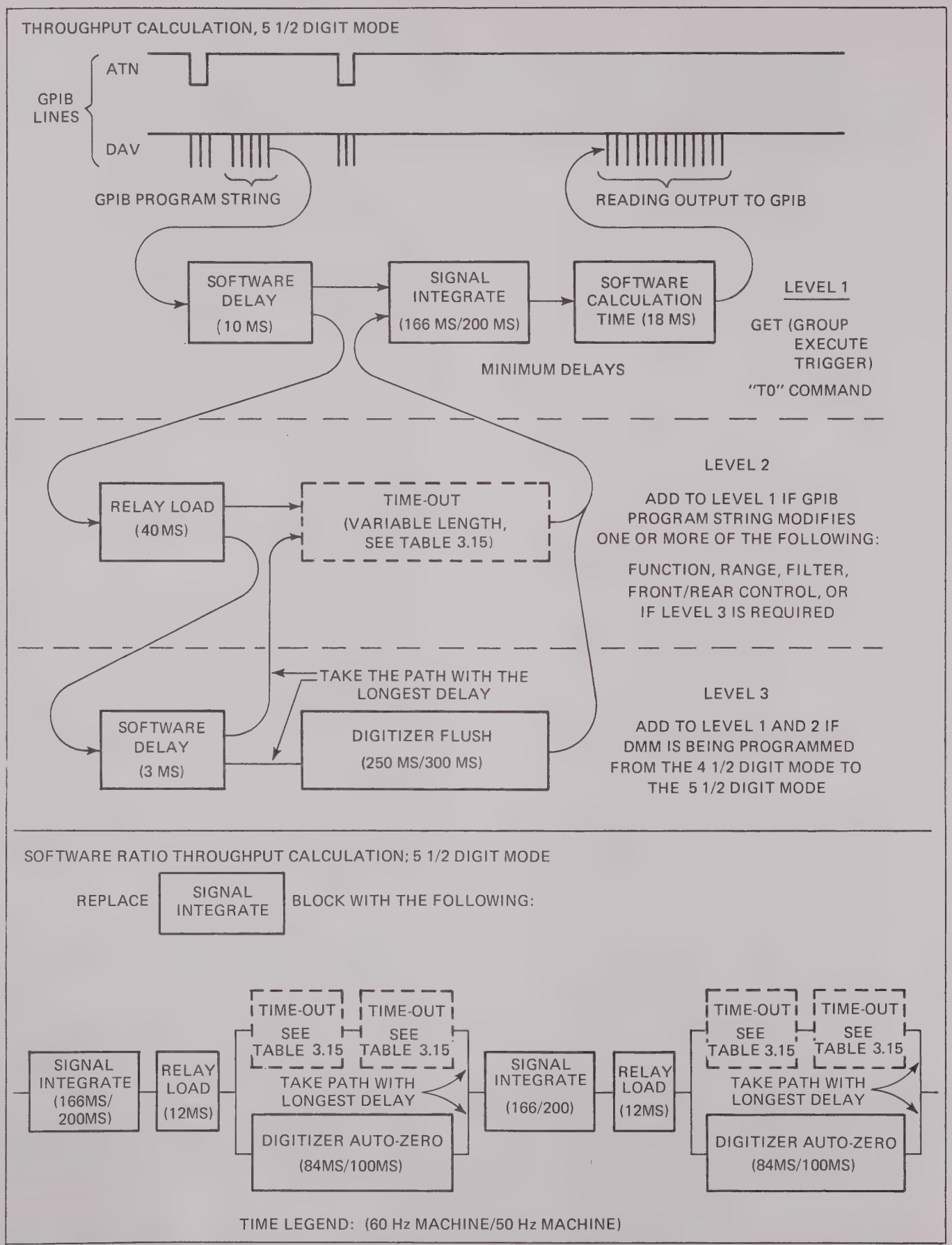

THROUGHPUT CALCULATION, 5 1/2 DIGIT MODE
GPIB LINES
ATN
DAV
GPIB PROGRAM STRING
READING OUTPUT TO GPIB
SOFTWARE DELAY (10 MS)
SIGNAL INTEGRATE (166 MS/200 MS)
SOFTWARE CALCULATION TIME (18 MS)
MINIMUM DELAYS
LEVEL 1
GET (GROUP EXECUTE TRIGGER)
"T0" COMMAND
RELAY LOAD (40MS)
TIME-OUT (VARIABLE LENGTH, SEE TABLE 3.15)
LEVEL 2
ADD TO LEVEL 1 IF GPIB PROGRAM STRING MODIFIES ONE OR MORE OF THE FOLLOWING:
FUNCTION, RANGE, FILTER, FRONT/REAR CONTROL, OR IF LEVEL 3 IS REQUIRED
TAKE THE PATH WITH THE LONGEST DELAY
SOFTWARE DELAY (3 MS)
DIGITIZER FLUSH (250 MS/300 MS)
LEVEL 3
ADD TO LEVEL 1 AND 2 IF DMM IS BEING PROGRAMMED FROM THE 4 1/2 DIGIT MODE TO THE 5 1/2 DIGIT MODE
SOFTWARE RATIO THROUGHPUT CALCULATION; 5 1/2 DIGIT MODE
REPLACE
SIGNAL INTEGRATE
BLOCK WITH THE FOLLOWING:
SIGNAL INTEGRATE (166MS/ 200MS)
RELAY LOAD (12MS)
TIME-OUT SEE TABLE 3.15
TIME-OUT SEE TABLE 3.15
TAKE PATH WITH LONGEST DELAY
DIGITIZER AUTO-ZERO (84MS/100MS)
SIGNAL INTEGRATE (166/200)
RELAY LOAD (12MS)
TIME-OUT SEE TABLE 3.15
TIME-OUT SEE TABLE 3.15
TAKE PATH WITH LONGEST DELAY
DIGITIZER AUTO-ZERO (84MS/100MS)
TIME LEGEND: (60 Hz MACHINE/50 Hz MACHINE)

*Figure 3.25 - 5 1/2 Digit Software Ratio Throughput Calculation*

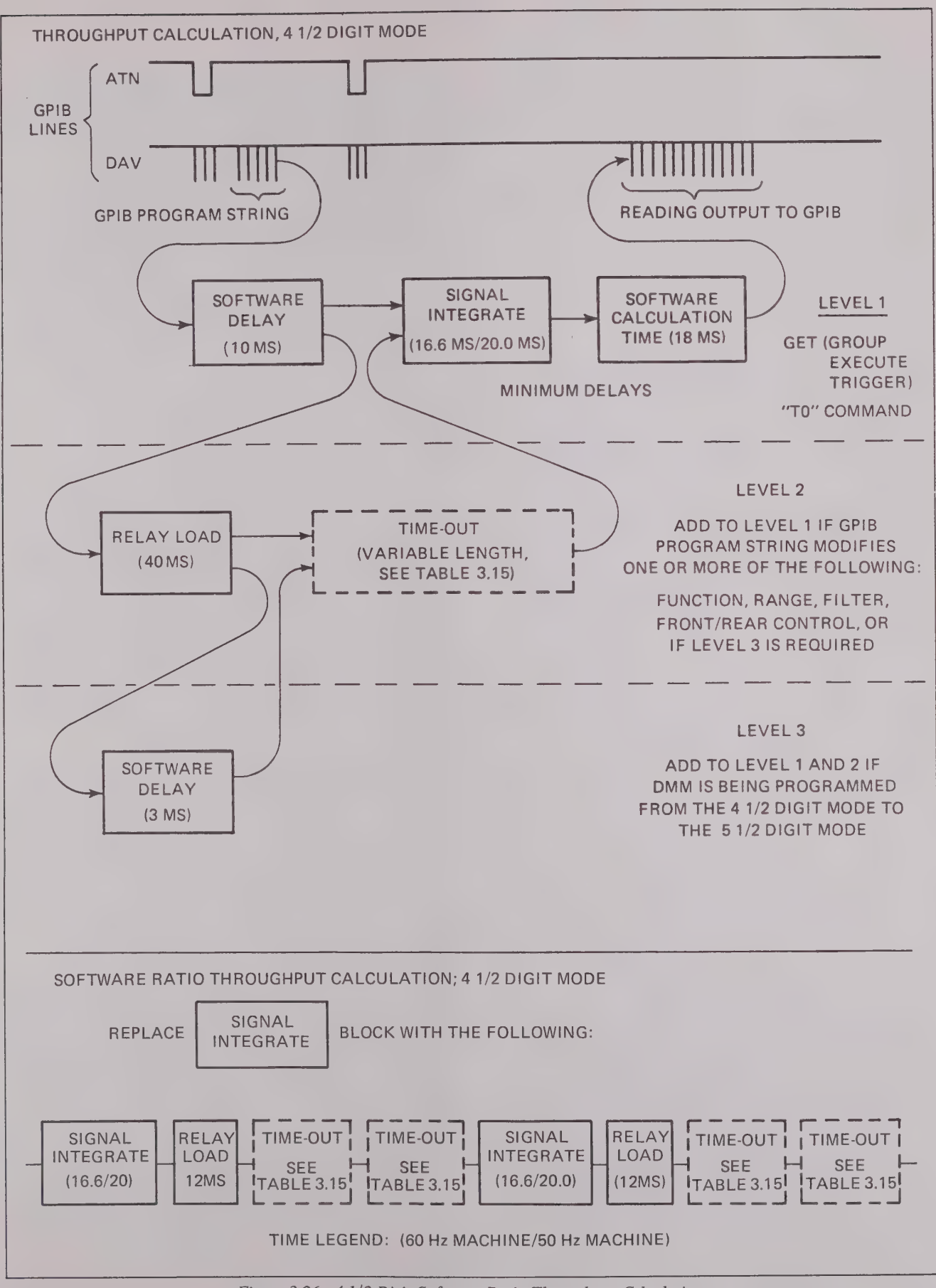

THROUGHPUT CALCULATION, 4 1/2 DIGIT MODE
GPIB LINES
ATN
DAV
GPIB PROGRAM STRING
READING OUTPUT TO GPIB
SOFTWARE DELAY (10 MS)
SIGNAL INTEGRATE (16.6 MS/20.0 MS)
SOFTWARE CALCULATION TIME (18 MS)
MINIMUM DELAYS
LEVEL 1
GET (GROUP EXECUTE TRIGGER)
"T0" COMMAND
LEVEL 2
ADD TO LEVEL 1 IF GPIB PROGRAM STRING MODIFIES ONE OR MORE OF THE FOLLOWING:
FUNCTION, RANGE, FILTER, FRONT/REAR CONTROL, OR IF LEVEL 3 IS REQUIRED
RELAY LOAD (40 MS)
TIME-OUT (VARIABLE LENGTH, SEE TABLE 3.15)
LEVEL 3
ADD TO LEVEL 1 AND 2 IF DMM IS BEING PROGRAMMED FROM THE 4 1/2 DIGIT MODE TO THE 5 1/2 DIGIT MODE
SOFTWARE DELAY (3 MS)
SOFTWARE RATIO THROUGHPUT CALCULATION; 4 1/2 DIGIT MODE
REPLACE
SIGNAL INTEGRATE
BLOCK WITH THE FOLLOWING:
SIGNAL INTEGRATE (16.6/20)
RELAY LOAD 12MS
TIME-OUT SEE TABLE 3.15
TIME-OUT SEE TABLE 3.15
SIGNAL INTEGRATE (16.6/20.0)
RELAY LOAD (12MS)
TIME-OUT SEE TABLE 3.15
TIME-OUT SEE TABLE 3.15
TIME LEGEND: (60 Hz MACHINE/50 Hz MACHINE)

*Figure 3.26 - 4 1/2 Digit Software Ratio Throughput Calculation*

to exchange various data. For an example, to transmit the string "F1R5CRLF" to the DMM (6 characters) 400 μS/character = 2.4 mS are required approximately.

3.7.3 The time necessary to PROGRAM, TRIGGER and OUTPUT a reading from the DMM is presented in Figure 3.25 and Figure 3.26. The Figure 3.25 is used when in the 5 1/2 digit mode or when in the 4 1/2 digit mode and the DMM is being programmed to the 5 1/2 digit mode. Figure 3.24 is used when the DMM is in the 4 1/2 digit mode or when the DMM is being programmed from 5 1/2 to 4 1/2 digit mode. Notice that the times shown do not include the actual bus time necessary to transfer data to or from the DMM, but this time can be estimated using Table 3.16. The throughput equations shown in the preceding 2 figures are based upon the assumption that the DMM is in 'HOLD' and is waiting to be triggered or re-programmed. This assumption is made because when not in hold, delays become much more difficult to estimate due to the random timing between incoming GPIB commands and readings already in progress. Since this section is an aid to computing the time required to obtain a reading, it is also assumed that each program string contains a DMM trigger such as the "T0" command, or is followed closely by a GET (Group Execute Trigger). This accounts for the 2 figures showing a Signal Integrate delay and also showing a reading being output to the GPIB.

3.7.4 Both Figures 3.25 and 3.26 show 2 GPIB lines at the top of the page. These are shown for reference only, and to identify when bytes are being transferred to or from the DMM. To ease the task of calculating DMM throughput, each figure is divided into three levels. Level 1 delays are the minimum delay that can occur whenever the DMM is programmed over the bus. GPIB commands which cause only level 1 delays are those commands which cause no modifications to the configuration. Examples of these are trigger commands, Null commands, R0 (auto-range) command, and Z (initialize) command. These are all processed very rapidly, and the majority of level 1 delays occur due to the "T0" or GET (Group Execute Trigger) which is assumed to accompany the program string.

3.7.5 If the GPIB command modifies one or more of the following: function, range, filter, front/rear control, then level 2 delays should be added to level 1 delays when performing delay calculations. Examples of commands which will cause a level 2 delay are: F1 (DC) if the DMM is in some other function, or R5 (10V range) if the DMM is in some other range. Note that level 2 delays will only occur if the GPIB command modifies the function, range, etc. For instance, if the DMM is already in DC and the "F1" command is sent, only level 1 delays will occur. Level 3 delays should be added if the DMM is being programmed from one digit mode (integrate time) to another. For example, if the DMM is in the 4 1/2 digit mode and an "I2" or "I3" command is received, the DMM will experience level 3 as well as level 1 and 2 delays.

**Table 3.16 - Typical GPIB Handshake Times**

| Bus Operation | Typical Time Req. |
|---|---|
| Handshake Interface Messages | 12 μS |
| Handshake and Process an Incoming String of Characters | 400 μS/Character |
| Output the Serial Poll Status Byte | 300 μS |
| Output a Reading (15 Characters) | 130 μS/Character |

## 3.8 DMM APPLICATIONS.

### 3.8.1 Purpose.

3.8.1.1 This subsection contains Bench and System application examples for the Model 5004 Digital Multimeter. Each example contains a statement of purpose along with keyboard or GPIB programming details. Paragraph 3.8.2 presents the Bench application (non-GPIB) while paragraph 3.8.3 presents the system application using an HP 9825 calculator connected to the DMM through the IEEE 488-1978 Standard Interface.

### 3.8.2 Bench Applications.

3.8.2.1 Purpose: Configure the DMM and 1200 Scanner to do the following:

a) Scan 5 noisy input signals at 1 hour intervals.

b) Read each input signal 4 times and average the 4 readings to reduce noise effects.

c) Store the averaged readings to the 5004's Data Buffer for later recall.

3.8.2.2 The DMM's Time function will be used to sequence the measurements, and the LAH function will be employed to average 4 readings into one to reduce noise effects. The 1200 scanner will accept trigger pulses from the DMM which will cause it to scan to the next channel. To prepare the Model 1200, do the following:

a) Turn AC power off.

b) Remove all relay cards except one, which should be installed in the location nearest to the power switch.

c) When triggered, the Model 1200 will scan channels 1, 2, 3 ... 9, 10 and then back to 1, etc. Since only 5 signals are to be scanned, the 10 channels should be paralleled as shown in Figure 3.27 (see 1200 manual for hookup details peculiar to the switch decade assembly being used).

3.8.2.3 After connecting the 1200 and the DMM as shown in Figure 3.28 and applying power, the key sequence shown in Table 3.17 is performed. The DMM will then begin sequence described below.

a) The system will remain dormant for approximately 12 minutes.

b) The DMM will take 4 readings at one-second intervals and average them.

c) The averaged reading will then be copied into the Data Buffer and also displayed.

d) The DMM will send a pulse to the scanner, causing it to sequence to the next input. (Go to step a)).

3.8.2.4 The timing diagram in Figure 3.29 shows the system timing as the first two inputs are measured, averaged, and stored into the buffer memory. Notice that as the sequence begins, no relay channels are selected. This causes the contents of buffer location 0 to be unuseable. Valid data can be found starting with buffer location 1.

3.8.2.5 The need for noise rejection required that the Time Function's subinterval and N registers be used to trigger multiple readings for averaging purposes. If this requirement did not exist, these Time registers could instead be used to allow the sampling of all 5 inputs within seconds of one another. The following changes would be required to bring this about:

a) LAH function disabled.

b) 1.0 programmed as Time 3 (Interval = 1 hour).

c) .0001* programmed as Time 4 (Subinterval = 1 second).
*2-4 seconds may be required for certain combinations such as Filter + Autorange.

d) 5 programmed as Time 5 (Number of readings = 5).

e) The Model 1200 should be pre-triggered, causing the first channel to be selected.

The resulting timing diagram is shown in Figure 3.30.

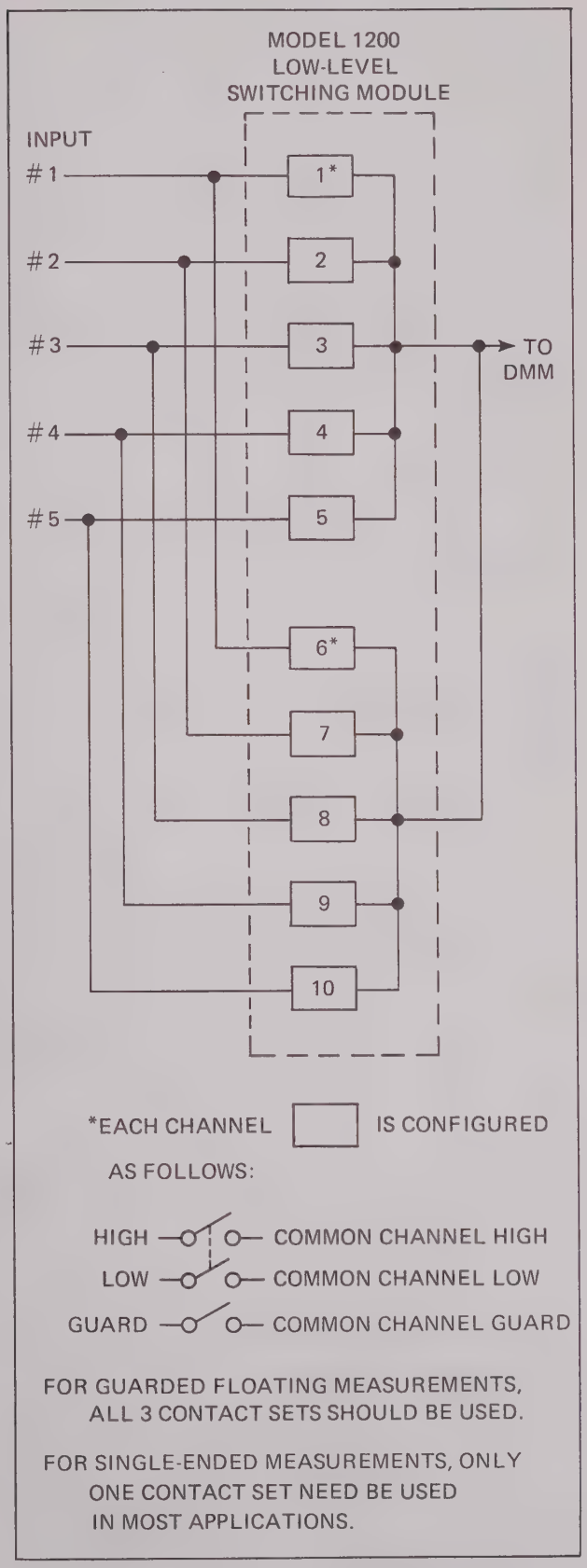



*Figure 3.27 - Wiring of Switching Module For Bench Application #1*

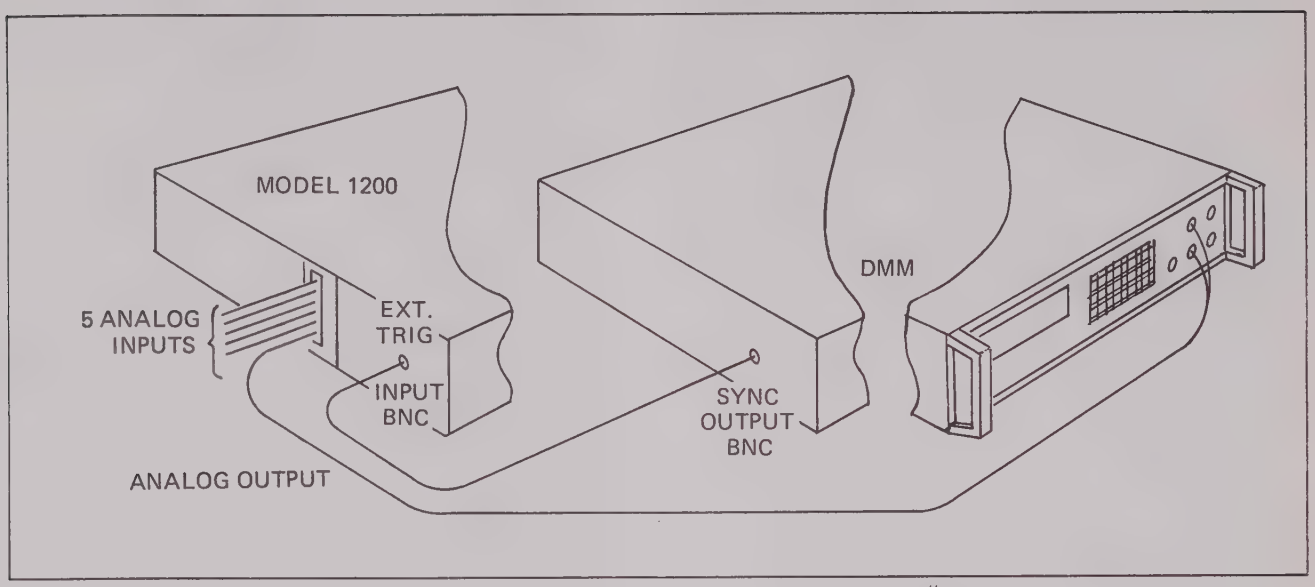



*Figure 3.28 - Signal Connections For Bench Application # 1*

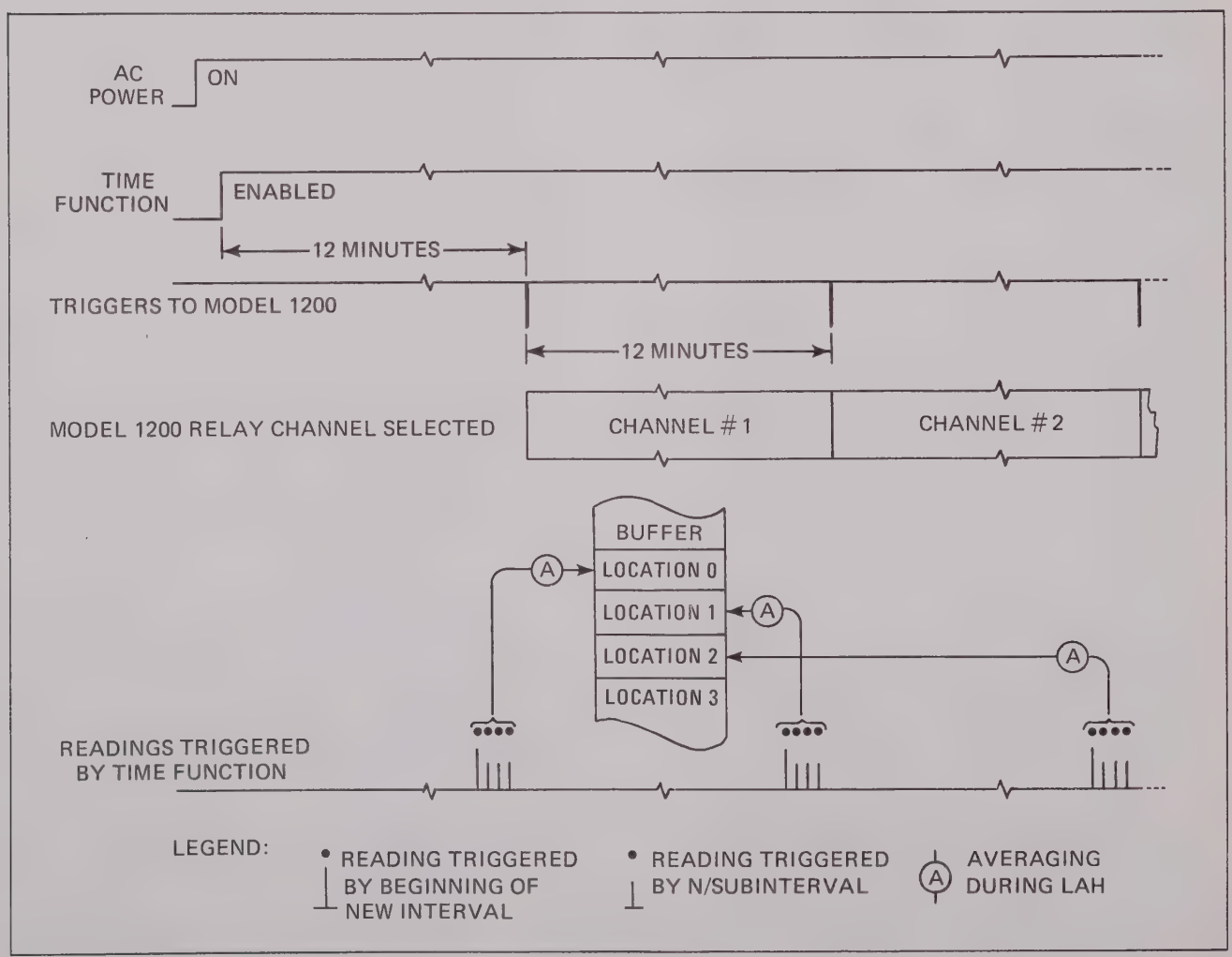



*Figure 3.29 - Read Timing For Bench Application # 1*

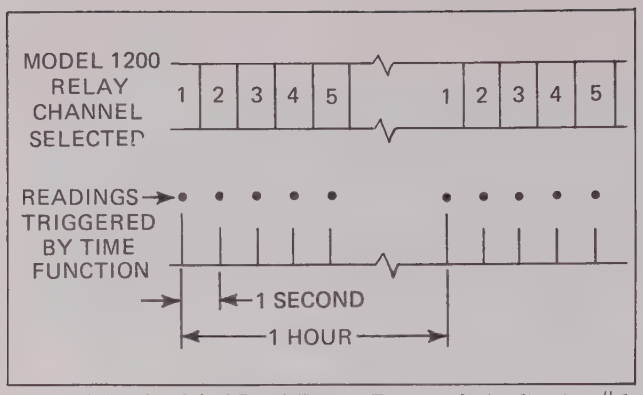



*Figure 3.30 - Modified Read Timing For Bench Application #1*

### 3.8.3 System Applications.

3.8.3.1 Each System Application example contains a program listing as printed by a calculator along with an explanation for each line of the program. If the DMM is to be used with a Hewlett-Packard Model 9825 calculator the programming presented in this section may be used directly and/or further modified to suit the users needs. Because the DMM may be used with any controller which operates on the standard interface bus the user may wish to prepare equivalent software for another controller device. In such a case the user should review the remote operating instructions contained in Section 3 of this manual to select and assemble appropriate operating statements for his controller which cause the transmission of the required interface messages and device dependent messages.

3.8.3.2 For example, in the first program sample in this section, line zero of the program is `rem 7` and the accompanying explanation indicates that this statement on the Hewlett Packard 9825 calculator sends the remote message to all devices on the bus. This statement causes the calculator to lower the REN line thus arming the DMM for remote operation.

3.8.3.3 Referring again to the first example note that line 1 of the program printout contains the statement `flt 6` and that the accompanying explanation indicates that this sets the floating decimal format. This may or may not be a feature or function of the controller in use and since it is not an interface or device dependent message use of an equivalent is at the discretion of the user. Line 2 of the program shows the statement `wrt 702,"zF1r5"`. The explanation indicates that this transmits the device listen address 02. The user should select the statement for his controller which causes it to transmit the listen address assigned to the DMM. Instructions for the address assignment of the DMM are presented in paragraph 3.5.5. Table 3.8 shows the address switch setting, the talk and listen address characters and data line binary code for each available decimal address of the instrument.

**Table 3.17 - Key Sequence For Bench Application #1**

| Step | Key Sequence | Comments |
|---|---|---|
| 1. | SHIFT | Press the SHIFT key as required. Note SHIFT annunciator for correct execution. |
| 2. | RESET | Clear all ESC functions. |
| 3. | SHIFT 0 1 STORE TIME | Set start time to 0. |
| 4. | SHIFT 9 9 STORE TIME 2 | Set stop time to infinity. |
| 5. | SHIFT • 1 2 STORE 3 TIME | Set interval to 12 minutes (= 1 hour/5). |
| 6. | SHIFT • 0 0 0 1 4 STORE TIME | Set subinterval to 1 second. |
| 7. | SHIFT 4 5 STORE TIME | Set N to 4 readings. |
| 8. | SHIFT 4 STORE LAH | Set LAH Average Cycle constant to 4. |
| 9. | SINGLE | Place instrument in Hold mode. |
| 10. | BUFF | Clear Data Buffer by depressing Buff key until word "CLRBUF" appears on display |
| 11. | LAH | Enable LAH and select Average by depressing LAH key until "A" appears, then release key. |
| 12. | TIME | Enable Time function. |

3.8.3.4 Line 2 of the example also contains the program string which is composed of the device dependent messages. The device dependent message is the primary subject to which this section of the manual addresses itself. The examples contained in this section are presented primarily to show the various combinations of device dependent messages used to accomplish the various remotely controlled measurement operations. Note that the program printout indicates the string of device dependent messages presented in the table directly above the program tape. This format is maintained throughout the section and thus the user may use this section conveniently by referring to the device dependent message string shown for each system operation example.

3.8.3.5 Line 3 of the program shown in the example instructs the DMM to become a talker and transmit the measurement data. Line 3 also instructs the calculator to store the measurement data transmitted by the DMM in a storage register known as "Variable A" and subsequentially to print the value in Variable A on the program tape. The final line on the program printout is the measurement value 7.985702e 00 the answer 7.9857 volts.

3.8.3.6 The accompanying pages present eight remote systems applications, listed sequentially one through eight. Tables and figures are included throughout the examples to assist in following the explanations.

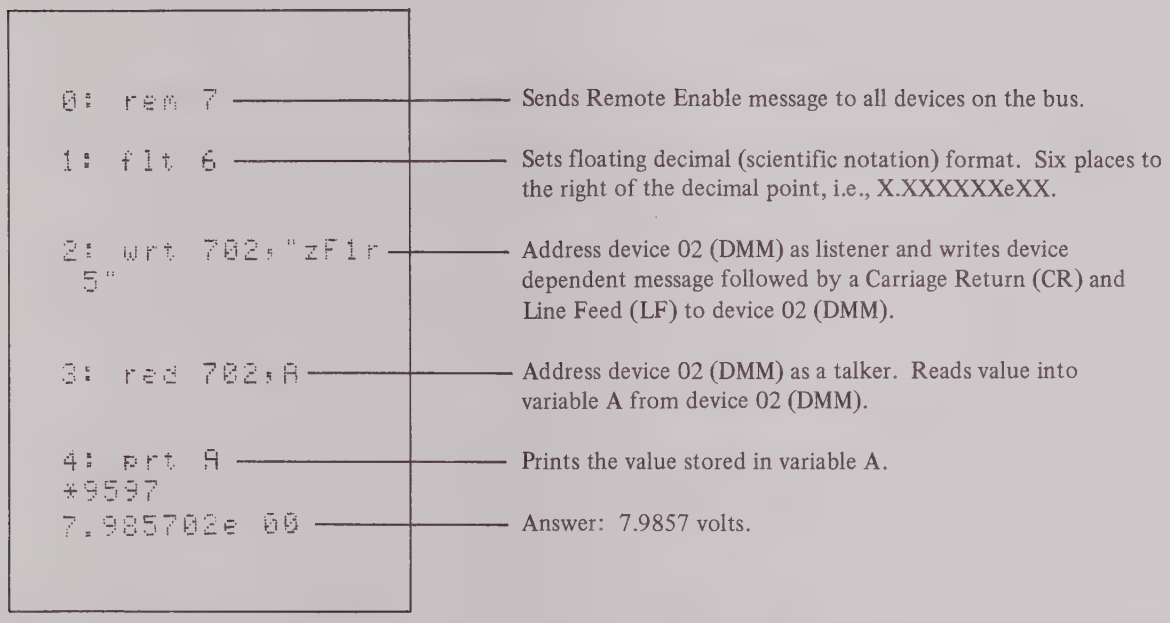
System Application # 1

Purpose: Remotely program the DC volts function to measure 7.9857 volts.

Program String: ZF1R5

Device Dependent Messages

| Device Code | Parameter |
|---|---|
| Z | Initialize, Internal Trigger |
| F1 | DC Volts |
| R5 | Range 5 (10 volts) |

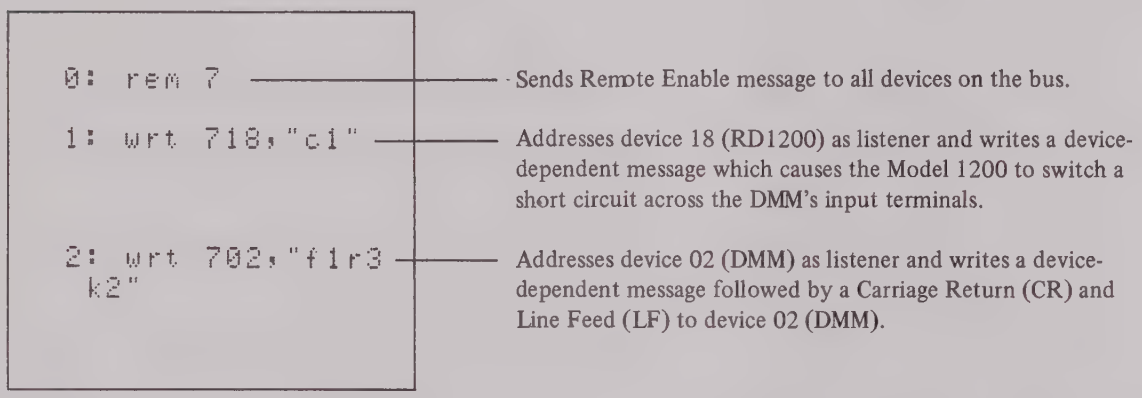

0: rem 7
Sends Remote Enable message to all devices on the bus.
1: flt 6
Sets floating decimal (scientific notation) format. Six places to the right of the decimal point, i.e., X.XXXXXXeXX.
2: wrt 702,"zF1r 5"
Address device 02 (DMM) as listener and writes device dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).
3: red 702,A
Address device 02 (DMM) as a talker. Reads value into variable A from device 02 (DMM).
4: prt A
Prints the value stored in variable A.
#9597
7.985702e 00
Answer: 7.9857 volts.

System Application #2

Purpose: Remotely program the DMM to zero itself against an externally-supplied short circuit, and to perform limited self-tests.

Program String: F1R3K2

| Device Code | Comments |
|---|---|
| F1 | DC volts |
| R3 | Range 3 (0.1 volts) |
| K2 | Zero command |


0: rem 7
1: wrt 718,"c1"
2: wrt 702,"f1r3
k2"
Sends Remote Enable message to all devices on the bus.
Addresses device 18 (RD1200) as listener and writes a device-dependent message which causes the Model 1200 to switch a short circuit across the DMM's input terminals.
Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

System Application #3

Purpose: Remotely program the DMM to the "Hold" mode and trigger 3 readings, each time using a different technique to trigger and/or recover the reading.

Program String: ZT3F1R5T0
D1T0
D1

| Program Code | Explanation |
|---|---|
| Z | Initialize |
| T3 | "Hold" mode |
| F1 | DC |
| R5 | Range 5 = 10V range |
| T0 | Trigger 1 reading |
| D1 | SRQ when data is ready |

(No. 3 continued)

```
0: rem 7
1: wrt 702,"zt3f
 1r5t0"
2: red 702,A
3: wrt 702,"d1t0
 "
4: on1 7,"GETUM"
5: eir 7
6: gsb "OTHERTAS
 K"
7: wrt 702,"d1"
8: trg 702
9: eir 7,0
10: gsb 'OTHERTA
 SK"
11: if band(rds(
 702),1)=0;gto
 10
12: red 702,C
13: fxd 6;prt A,
 B,C
14: stp
15:
16: "GETUM":if
 band(rds(702),
 1)=0;eir 7;iret
17: red 702,B
18: iret
19:
20: "OTHERTASK":
21: wait 1000
22: ret
*26549
```

Sends Remote Enable message to all devices.

Address device 02 (DMM) as listener and writes device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

Address device 02 as a talker. Reads value into Variable A from device 02 (DMM).

Address device 02 (DMM) as listener and writes device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

Upon receiving a Service Request (SRQ) from the bus, the controller will interrupt its present task and transfer control to the line labeled "GETUM" (line 16).

Enable interrupts from the bus.

Go to subroutine "OTHERTASK" while waiting for the reading to complete.

Address device 02 (DMM) as listener and writes device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

Address device 02 (DMM) as listener and send Group Execute Trigger.

Disable interrupts from the bus.

Go to subroutine "OTHERTASK" while waiting for the reading to complete.

Reads the DMM's status byte and checks to see if the Data Ready bit is set. If not, repeat subroutine "other task".

Address device 02 as a talker. Reads value into Variable A from device 02 (DMM).

Sets the format for printer output and prints variables A, B and C.

Stops program execution.

Interrupt Routine: Reads the DMM's status byte and checks to see if the Data Ready bit is set. If not, enable the interrupt once again and return from interrupt.

Address device 02 as a talker. Reads value into Variable A from device 02 (DMM).

Return from interrupt.

Subroutine "Othertask" executes while controller is waiting for DMM's reading to complete. A simple delay is used in this example, but useful work can take place while waiting for readings.

```
 0.240918
14.993000
14.568900
```

Printout of Variables A, B and C.

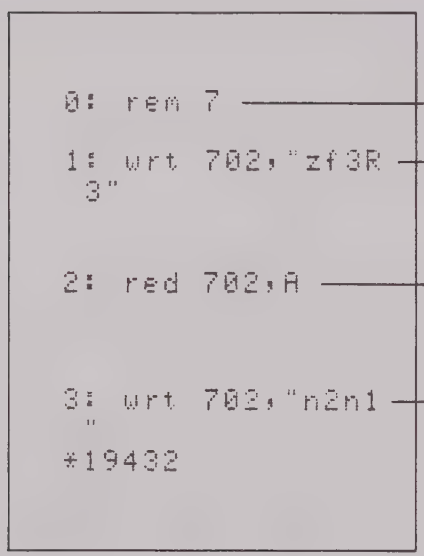
System Application #4

Purpose: Remotely program the Ohms function and compensate for (2-wire) lead resistance by storing a reference reading as the Null constant and enabling the Null function.

Program String: ZF3R3
N2N1

Device-Dependent Messages:

| Device Code | Parameter |
|---|---|
| Z | Initialize, Internal trigger |
| F3 | Ohms function |
| R3 | 0.1K Ohm range |
| N2 | Store as Null constant |
| N1 | Enable Null function |




Sends Remote Enable message to all devices on the bus.

Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

Address device 02 (DMM) as a talker. Reads value into Variable A from device 02 (DMM). This program line ensures that a reading is completed before the next program line is executed.

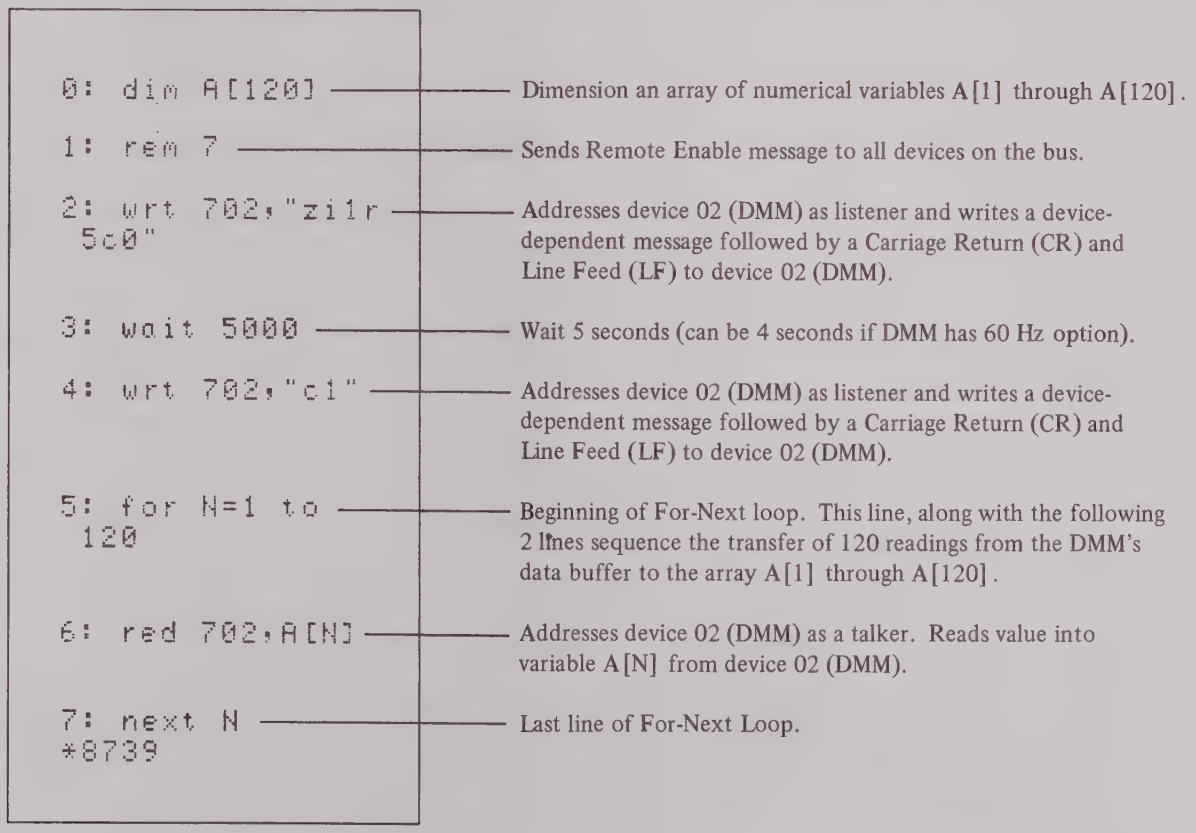
Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

System Application #5

Purpose: Remotely program the DMM to trigger itself at high speed and store the resulting readings to the Data Buffer. The first 120 readings are then retrieved from the Data Buffer over the bus.

Program String: ZI1R5C0
C1

| Device Code | Comments |
|---|---|
| Z | Initialize, Internal Trigger |
| I1 | High-Speed Mode (4-1/2 Digits) |
| R5 | Disable Autorange |
| C0 | Clear the Data Buffer |
| C1 | Output Data Buffer to GPIB |

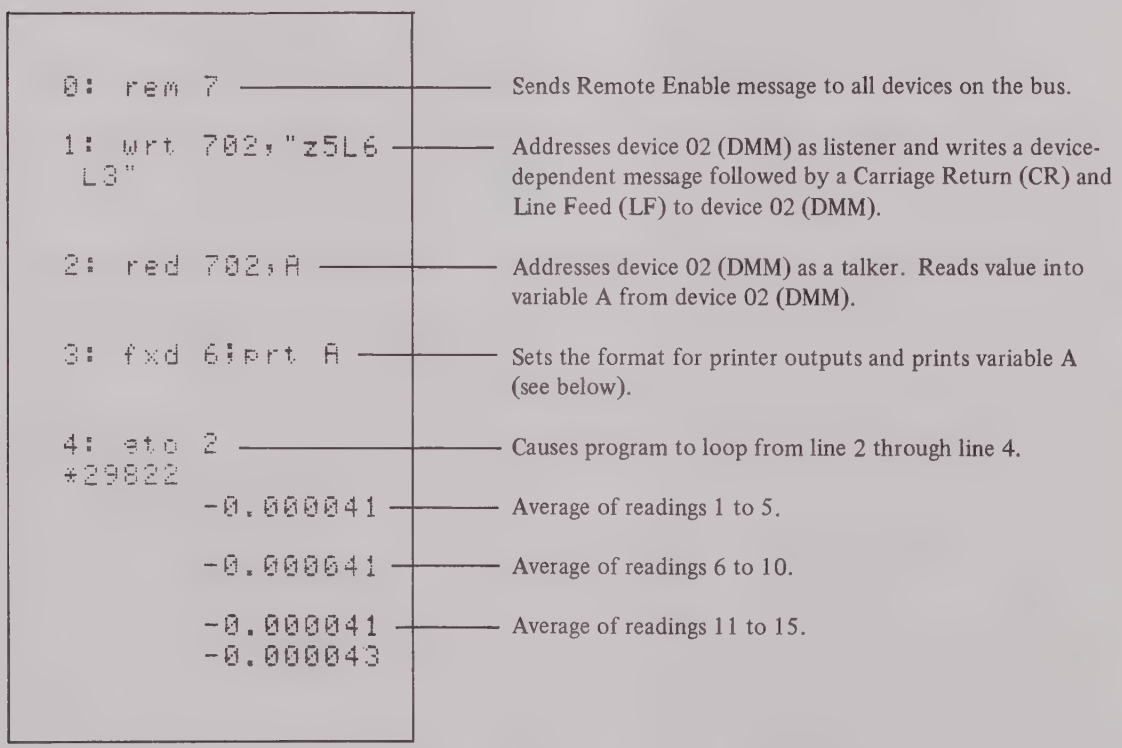

0: dim A[120]
Dimension an array of numerical variables A[1] through A[120].
1: rem 7
Sends Remote Enable message to all devices on the bus.
2: wrt 702,"zi1r 5c0"
Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).
3: wait 5000
Wait 5 seconds (can be 4 seconds if DMM has 60 Hz option).
4: wrt 702,"c1"
Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).
5: for N=1 to 120
Beginning of For-Next loop. This line, along with the following 2 lines sequence the transfer of 120 readings from the DMM's data buffer to the array A[1] through A[120].
6: red 702,A[N]
Addresses device 02 (DMM) as a talker. Reads value into variable A[N] from device 02 (DMM).
7: next N
*8739
Last line of For-Next Loop.

System Application #6

Purpose: Remotely program the LAH function to average readings in groups of 5, and then output the average to the display and to the bus.

Program String: Z 5L6L3

| Device Code | Comments |
|---|---|
| Z | Initialize, Internal Trigger |
| L6 | Store Entered Constant (5.0) as the LAH Average cycle count, C |
| L3 | Enable LAH and select the Average as the Output. |


0: rem 7
Sends Remote Enable message to all devices on the bus.
1: wrt 702,"z5L6 L3"
Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).
2: red 702;A
Addresses device 02 (DMM) as a talker. Reads value into variable A from device 02 (DMM).
3: fxd 6;prt A
Sets the format for printer outputs and prints variable A (see below).
4: sto 2
Causes program to loop from line 2 through line 4.
*29822
-0.000041
Average of readings 1 to 5.
-0.000041
Average of readings 6 to 10.
-0.000041
Average of readings 11 to 15.
-0.000043

System Application #7

Purpose: Remotely program the DMM to capture the minimum and maximum percentage deviation over a series of 10 or more readings*.

Program String: Z R5 3.75P2P1 10LGL3
L7

| Device Code | Comments |
|---|---|
| Z | Initialize, Internal Trigger |
| R5 | Range 5 (10V or 10KΩ range) |
| P2 | Store entered constant (3.75) as the percent constant |
| P1 | Enable Percent function |
| L6 | Store entered constant (10.0) as the LAH cycle count C |
| L3 | Enable LAH and select the Average as the output |
| L7 | Transmit LAH constants: Low, Average, High, N, C |

*A slow controller may have difficulty retrieving the LAH constants before an 11th reading has been completed. In this case the LAH constants will be affected by 11 readings rather than 10.

If desired, the controller can use the D1 command to cause a single SRQ to be issued after the tenth reading, thus allowing the controller's response to be interrupt-driven rather than polling the DMM as shown below.

```
0: rem 7
1: wrt 702,"zr5
 3.75p2p1 10L6L3
"
2: red 702,A
3: wrt 702,"L7"
4: red 702,L,A,H
5: fxd 6;prt L,H
#13982
       -10.124700
        -6.364260
```

Sends Remote Enable message to all devices on the bus.

Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

Addresses device 02 (DMM) as a talker. Reads value into Variable A from device 02 (DMM). This program line ensures that 10 readings have been completed before the next program line is executed.

Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and Line Feed (LF) to device 02 (DMM).

Addresses device 02 (DMM) as a talker. Reads value into variables L, A and H from device 02 (DMM). Note that the L7 command made 5 numbers available for output but only the first and third are of interest in this application, therefore the 4th and 5th are not read.

Sets the format for printer output and prints variables L and H (see below).

Lowest Percentage deviation from 3.75.

Highest Percentage deviation from 3.75.

System Application #8

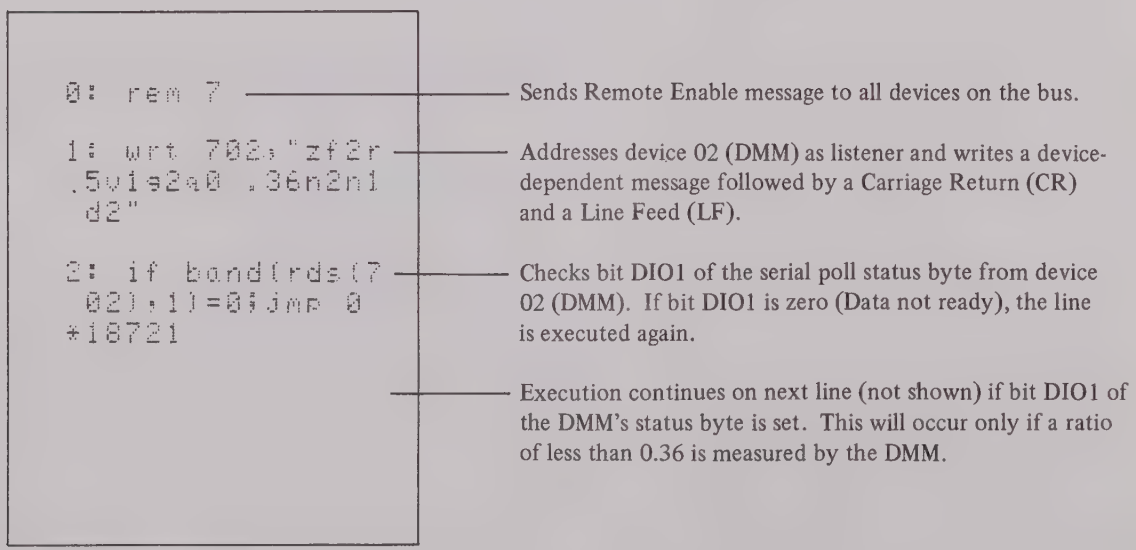
Purpose: Remotely program the Software Ratio and Null functions along with the Interrupt commands to do the following:

a) Configure the DMM as an AC ratiometer with a 1-10 VAC signal applied to the rear input and a 30 VAC reference connected to the front input terminals.

b) Use null along with the Interrupt commands so that the controller receives an SRQ if the ratio reading is less than 0.36.

Program String: ZF2R5V1G2Q0 .36N2N1D2

| Device Code | Comments |
|---|---|
| Z | Initialize, Internal Trigger |
| F2 | AC Volts |
| R5 | Range 5 (10V range) |
| V1 | Rear Input |
| G2 | External Reference, AC function |
| Q0 | External Reference Autorange |
| N2 | Store entered constant (0.36) as Null constant |
| N1 | Enable Null function |
| D2 | Send SRQ if reading –Null is negative |


0: rem 7
1: wrt 702,"zf2r .5v1s2a0 .36n2n1 d2"
2: if bond(rds(7 02),1)=0;jmp 0
*18721
Sends Remote Enable message to all devices on the bus.
Addresses device 02 (DMM) as listener and writes a device-dependent message followed by a Carriage Return (CR) and a Line Feed (LF).
Checks bit DIO1 of the serial poll status byte from device 02 (DMM). If bit DIO1 is zero (Data not ready), the line is executed again.
Execution continues on next line (not shown) if bit DIO1 of the DMM's status byte is set. This will occur only if a ratio of less than 0.36 is measured by the DMM.

# SECTION 4 THEORY OF OPERATION

## 4.1 GENERAL.

4.1.1 This section presents the circuit description for the DMM as the signal propagates from the input terminals to the front panel display or the rear panel General Purpose Interface connector. The text will refer to simplified diagrams, schematics and other aids which may be required to enhance the general description.

4.1.2 The physical configuration drawing illustrated in Figure 4.1 is an exploded chassis view which displays the DMM main sections comprising the main PCB. The numbers identified with each section are the discussion sequence followed in the text. The DMM block diagram is presented on Figure 4.1A.

## 4.2 POWER SUPPLIES.

4.2.1 The DMM is designed to operate from a wide range of AC line voltages and frequencies with 120 VAC and 60 Hz considered standard. The transformer design includes a selectable multi-tapped primary winding to accommodate line voltages of 100, 120, 220, and 240 VAC ± 10%, 47 through 440 Hz. A multi-tapped secondary with three separate windings develop the low voltage DC supplies required to power the DMM circuits.

4.2.2 The primary windings are wrapped with a shield, transformer terminal 6 and the shield is connected to the DMM chassis. The chassis is connected to power line ground through the power receptacle, J209. The analog windings have two additional shields for maximum isolation and common mode rejection. The guard shield, transformer terminal 18 extends through the analog section of the PCB with two aluminum shields guarding the analog circuits. The inner shield, transformer terminal 17 is connected to analog common.

4.2.3 From the three secondary windings, low voltage DC supplies are generated to power the main sections of the DMM. The voltage levels designators and grounds appearing

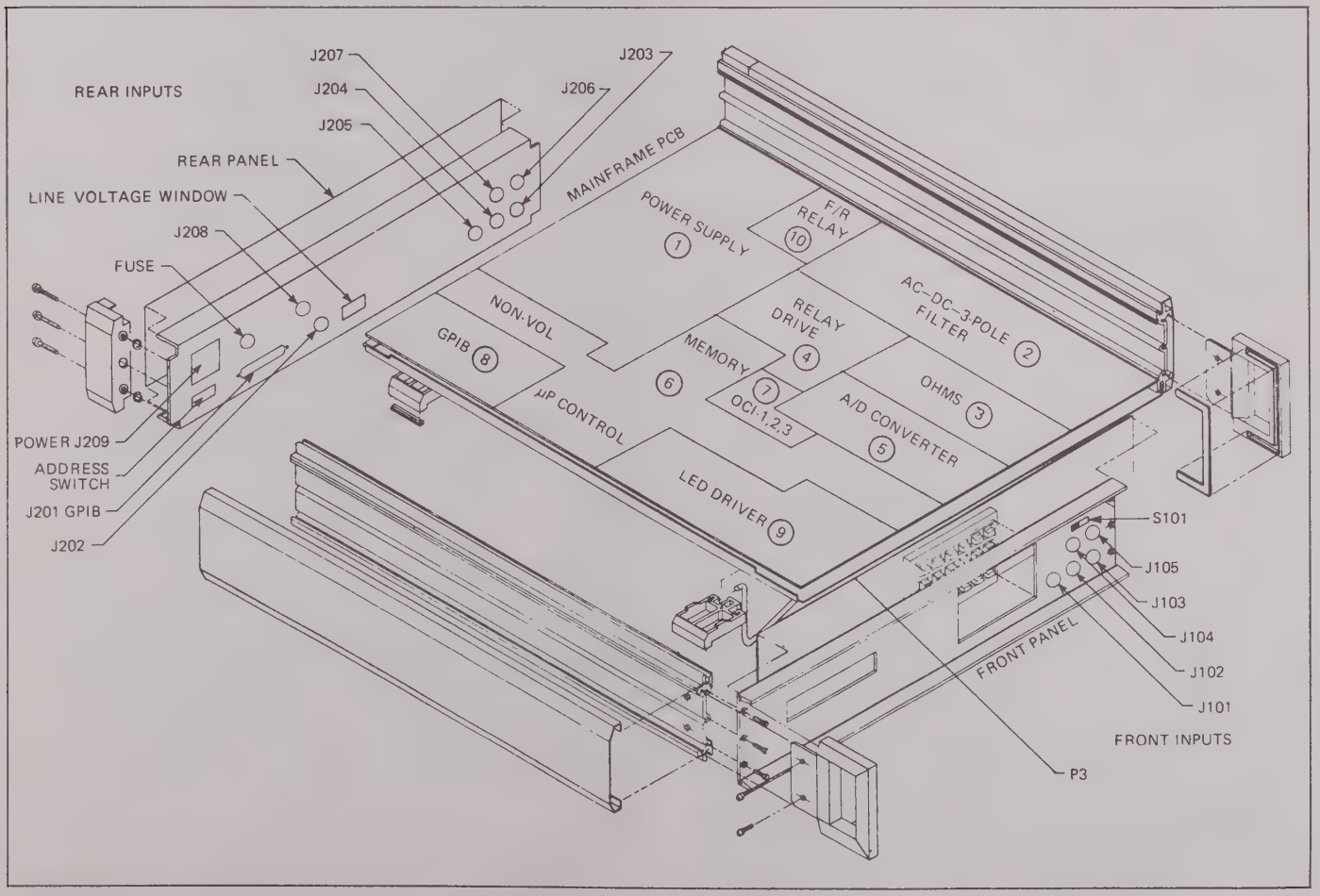



*Figure 4.1 - Model 5004 Physical Configuration*

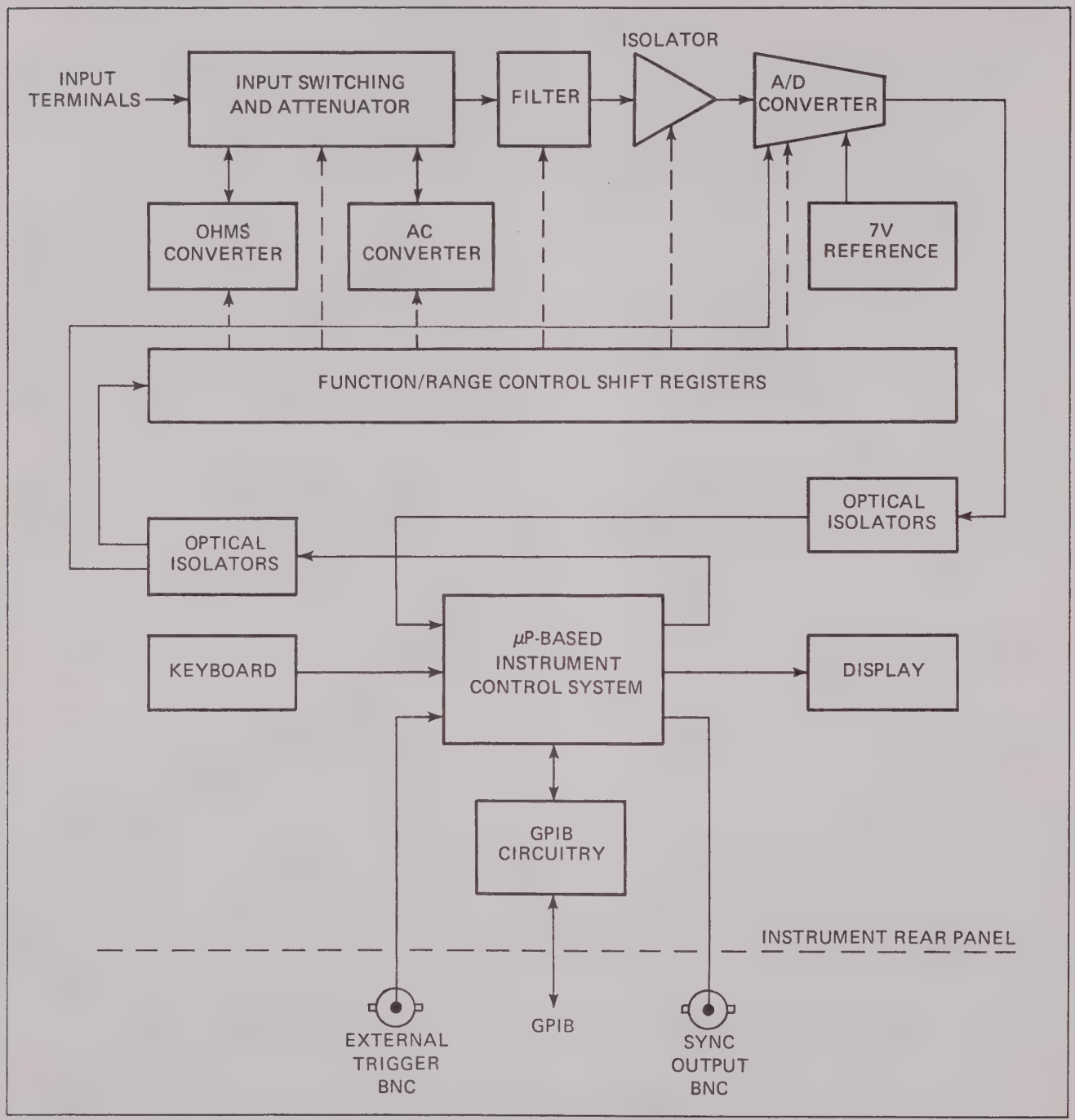



*Figure 4.1A - DMM Block Diagram*

on the power supply schematic, page 6-5, are used on all schematics; this is a sound troubleshooting aid.

## 4.3 ANALOG SUBSECTION.

### 4.3.1 Analog Hardware.

4.3.1.1 The Analog section of the DMM is positioned in the Guard area of the PCB assembly. This includes Section 2, 3, 4 and 5 of the board as shown in Figure 4.1, an exploded view of the DMM.

4.3.1.2 The Analog section, as shown in block diagram Figure 4.2, consists of the following basic subsections: Input Attenuator, Selectable 3-pole Active Filter, Variable gain Isolator, Variable gain AC Scaling Amplifier, True RMS AC converter, Ohms Amplifier and a Variable Ohms Current Source. A description for each function follows in this section.

### 4.3.2 Function and Range Switching.

4.3.2.1 The DMM's Function and Range are controlled by keyboard inputs, or GPIB commands. Upon receiving these signals, the microprocessor sends a new bit pattern to the function/range control shift-registers in order to energize the proper relays, and supply proper logic levels to other hardware.

4.3.2.2 The relays controlling the Function selection are K1, K8, K11 and K12. The relay closures for each function are tabulated in the following chart.

**Table 4.1 - Function Relay Chart**

| FUNCTION | K1 | K8 | K11 | K12 |
|---|---|---|---|---|
| DC | | | | |
| AC | | | | ▒ |
| OHMS | ▒ | ▒ | ▒ | ▒ |

▒ ENERGIZED

In the DC Function, all Function relays are de-energized and DC measurement signals are routed through the DC Input attenuator to the Isolator. In the AC Function, K12 is energized, routing the input signal to the Scaling amplifier and the RMS converter. The output signal from the RMS converter is applied to the DC Input attenuator. Attenuator relay K9 is energized in AC and OHMS ranges and does not attenuate the RMS converter output as the signal inputs the Isolator.

4.3.2.3 In the OHMS Function, relays K1, K8, K11 and K12 are energized, switching the Ohms Current Source and Ohms Amplifier into the configuration shown in Figure 4.4. The Function relay chart, Table 4.1 indicates the energized relays for the Ohms Function. The ranges for each function are selected by relays K2, K3, K4, K5, K6, K7 and K9. The Range Relay chart for each Function and Range is shown in Table 4.2, the next chart.

**Table 4.2 - Range Relay Chart**

| FUNCTION | RANGE | K2 | K3 | K4 | K5 | K6 | K7 | K9 |
|---|---|---|---|---|---|---|---|---|
| DC | .1V | | | | | | | ▒ |
| | 1V | | | | | | | ▒ |
| | 10V | | | | | | | ▒ |
| | 100V | | | | | | | |
| | 1KV | | | | | | | |
| AC | 1V | | | | | | | ▒ |
| | 10V | | | | ▒ | | | ▒ |
| | 100V | | | ▒ | | | | ▒ |
| | 1KV | | ▒ | | | | | ▒ |
| OHMS | .1KΩ | | | | | ▒ | ▒ | ▒ |
| | 1KΩ | | | | | ▒ | | ▒ |
| | 10KΩ | ▒ | | ▒ | | | | ▒ |
| | 100KΩ | | ▒ | ▒ | | | | ▒ |
| | 1000KΩ | | | ▒ | | | | ▒ |
| | 10,000KΩ | | | | ▒ | | | ▒ |

▒ ENERGIZED

This group of relays direct and scale the signal from the INPUT terminals to the Isolator input. The Isolator output signal voltage is scaled by Q15, 16, 17 and K9 as listed in Table 4.3, the Isolator Range chart, which follows next.

**Table 4.3 - Isolator Range Chart**

| RANGE | K9 ÷ 100 | Q16 X1 | Q15 X10 | Q17 ÷ 10 | ISOLATOR GAIN |
|---|---|---|---|---|---|
| .1V | ▒ | | ▒ | | 10 |
| 1V | ▒ | ▒ | | | 1 |
| 10V | ▒ | | | ▒ | .1 |
| 100V | | ▒ | | | 1 |
| 1000V | | | | ▒ | .1 |

▒ RELAY ENERGIZED OR FET SWITCH ON.

### 4.3.3 DC Volt Function.

4.3.3.1 The DMM is basically a DC measuring instrument. The DC signal conditioner, which is common to AC and OHMS, performs three functions: scaling the input signal to

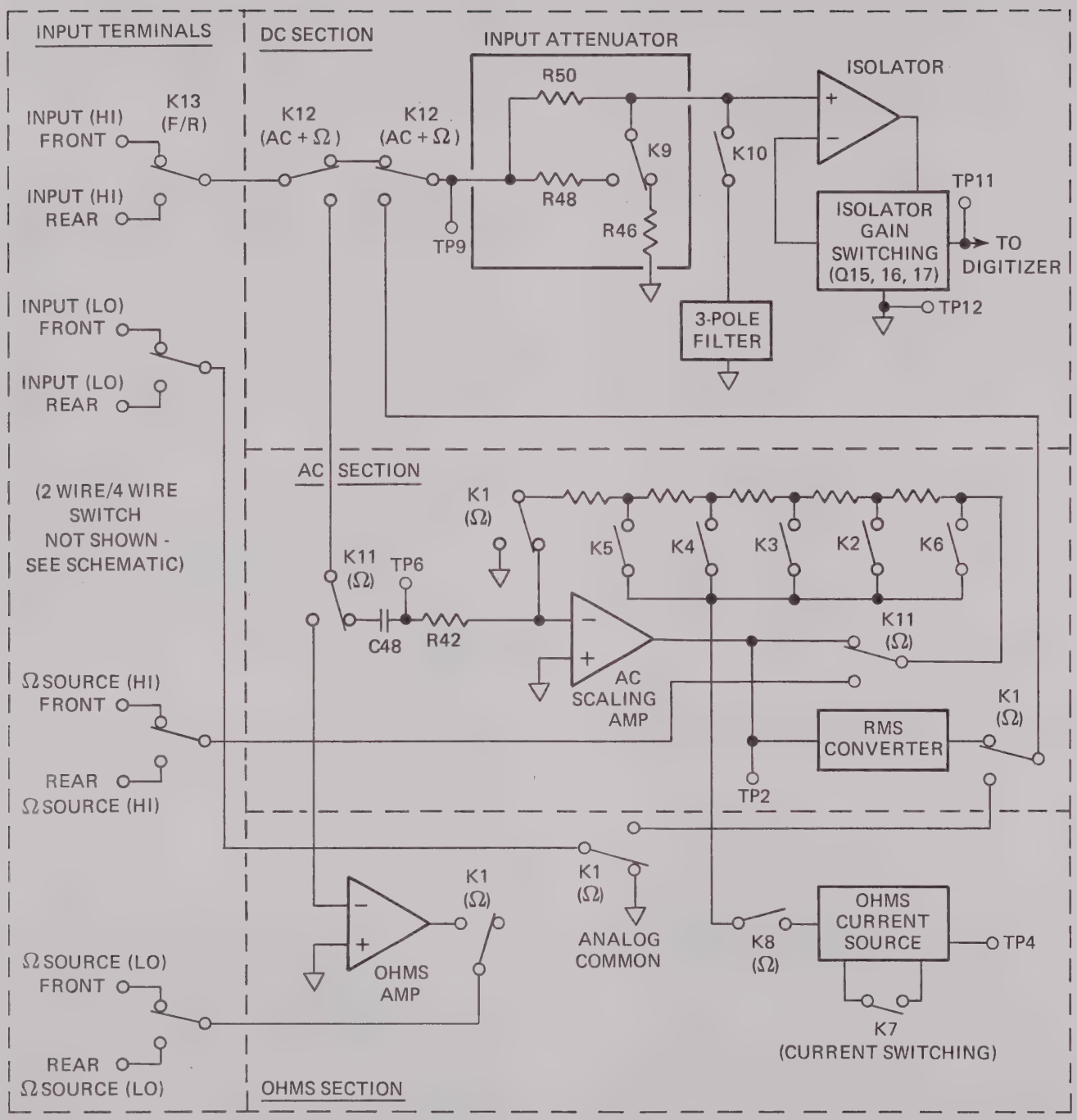



*Figure 4.2 - Analog Signal Conditioning Block Diagram*

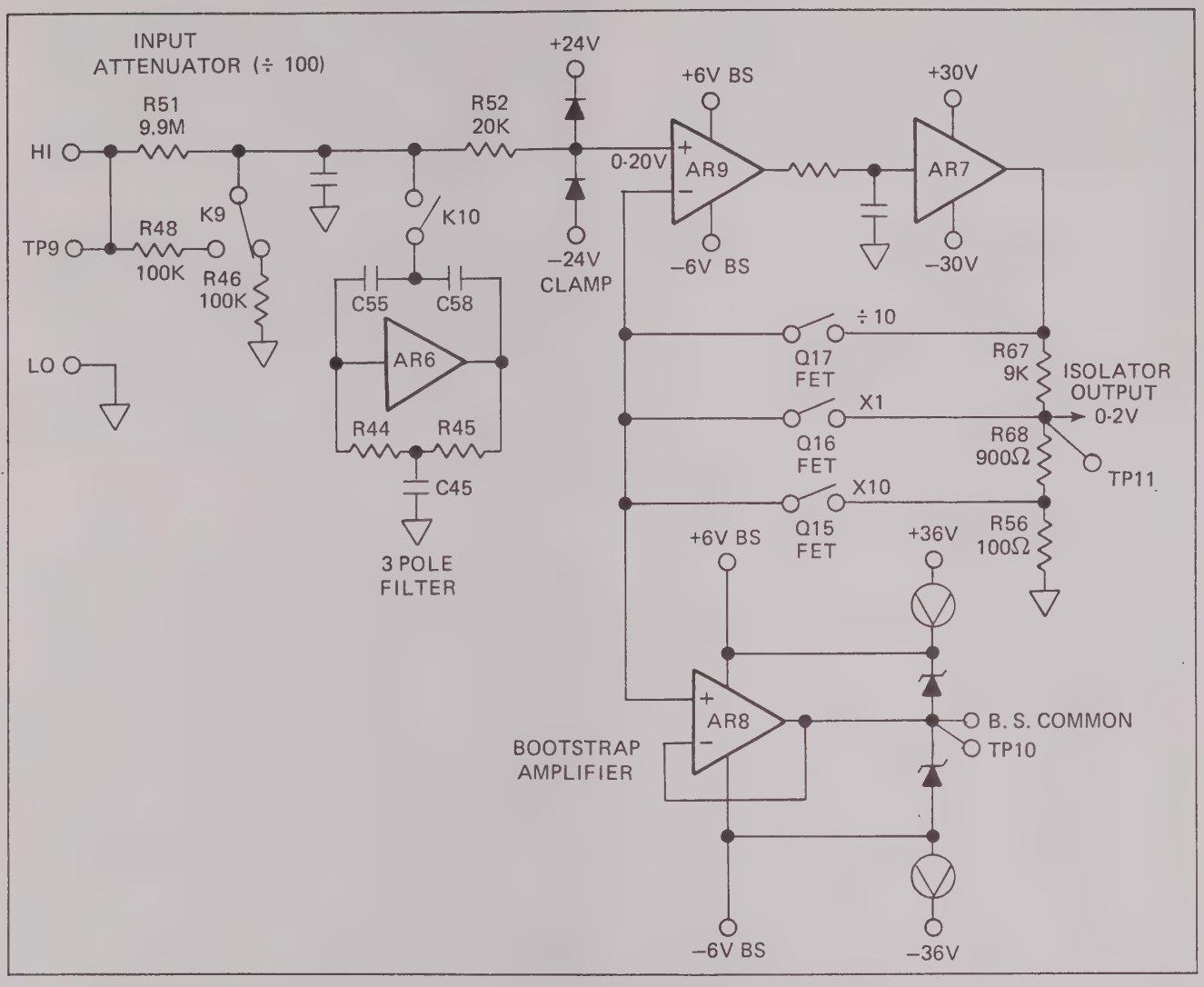



*Figure 4.3 - DC Volts Signal Conditioner*

one volt full scale; filtering the signal to reduce unwanted noise; isolating the source from loading effects. The DC signal conditioning is performed by the Input Attenuator, Isolator, and Filter. A simplified diagram of this circuit is shown in Figure 4.3. The complete block diagram showing the relationship to other parts of the analog section is shown in Figure 4.2.

4.3.3.2 The DC signal applied to the DMM INPUT terminals is routed through the front/rear relay K13, and AC/OHM relay K12 to the DC Input attenuator. If the .1, 1 and 10 volt range is selected, the Attenuator relay K9 is energized and the input voltage is routed with no attenuation to the Isolator input. In this mode R48 parallels R51. This provides overload current limiting and forms part of the three-pole active filter. If the 100 or 1K volt ranges are selected, K9 is de-energized, completing a voltage divider of R51 and R46, attenuating the input signal 100:1 before application to the Isolator.

4.3.3.3 A User selectable three-pole active filter is switched in or out of the circuit at the Isolator input by relay K10. The filter consists of op-amp AR6, capacitors C45, C55, C58 and resistors R44, R45. Relay K10 can be enabled either via the keyboard or GPIB. The filter provides attenuation of noise frequencies above 10 Hz. Filter response is at least 35 dB down at 50 Hz and attenuates 18 dB/Octave to −60 dB or greater.

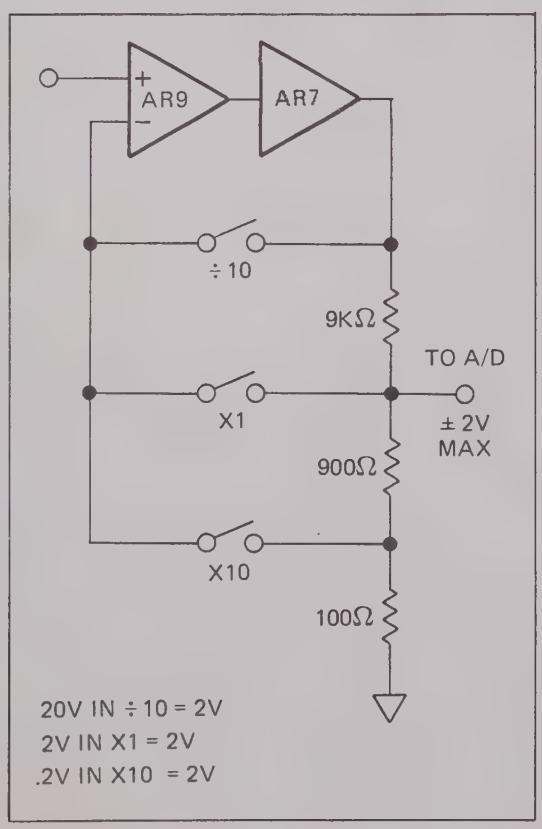
### 4.3.4 Isolator.

4.3.4.1 The Isolator contains an Input-Clamp, a high open-loop gain amplifier, bootstrap amplifier, and a gain switching network controlled by the range and function logic. A simplified diagram is presented in Figure 4.3 and the Isolator Range chart is shown in Table 4.3.

4.3.4.2 The Isolator accepts varying voltages at its input from zero to ± 20 VDC, depending on the signal input and the range selected. The amplifier is non-inverting with a closed loop gain of 10, 1 or 0.1 depending on the DMM range selected. Inputs are thus scaled to ± 1 volt full scale level (± 2 volts with 100% over-range) and applied to the Digitizer. Input overloads are clamped at ± 24 volts.

4.3.4.3 The non-inverting configuration combined with the bootstrap amplifier increases the input resistance of the Isolator to over 1000 megohms. A high open loop gain is achieved by the use of two operational amplifiers, AR9 and AR7. The output of AR7 is applied to a feedback network consisting of R67, R68 and R56. Listed next is Table 4.4, which charts scale factors the Isolator gain-switching (or attenuation) and Figure 4.2 shows a simplified diagram of the Isolator feedback network.

**Table 4.4 - Isolator Gain Switching**




When FET switch Q17 is closed, the output of AR7 is connected directly to the inverting input of AR9 as negative feedback. The closed loop gain to the output of AR7 is ONE, but since the output is tapped from the junction of R67 and R68, the overall Isolator gain is 0.1. When Q17 is closed, the overall gain is ONE and closing Q15 provides a gain of 10.

4.3.4.4 The BOOTSTRAP amplifier, AR8 and associated components, senses the Isolator feedback voltage (which tracks the input) and provides bootstrapped voltages (BSV) approximately 6 volts higher and 6 volts lower than the input to power AR9. The ± BSV on AR9 tracks the input to the Isolator which increases its input resistance above the level achievable without BSV. The output from AR7 (BS COMMON) drives the input bias current network to prevent it from shunting the input resistance.

### 4.3.5 Ohms Function.

4.3.5.1 The resistance measurement system shown in Figures 4.4 and 4.5 contain the ohms amplifier, voltage reference, current source, open input clamp and input over-voltage clamp. In operation, a fixed and stable current source is generated for each range and the current is fed through the resistance to be measured. The voltage drop across the resistor is proportional to the unknown resistance Rx. This voltage is read by the DMM and displayed as kilohms on the display. The current supplied provides a full scale DMM reading when the unknown resistance is equal to the range selected. For an example, the measuring of 10 kilohms on the 10 range produces a DMM readout of 10.0000.

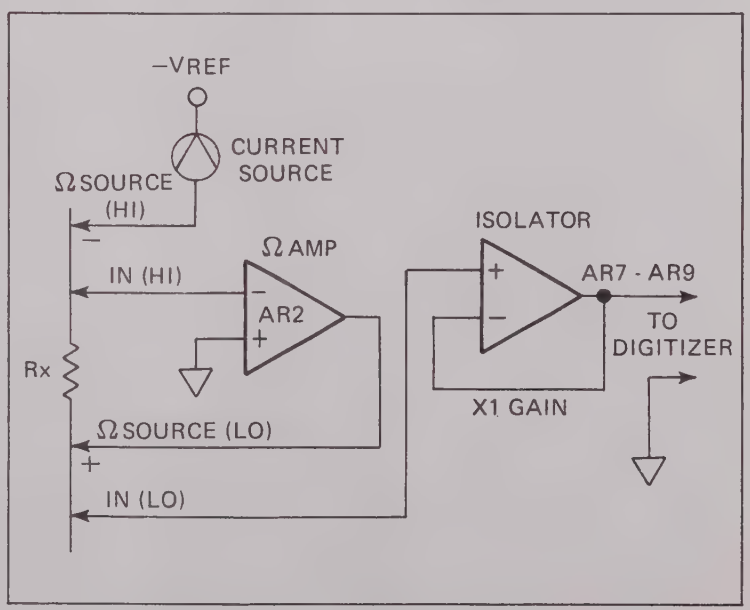



*Figure 4.4 - Resistance Measurement System*

4.3.5.2 The Ohms current source utilizes an accurate reference voltage to generate a reference current source through the resistor divider and current switching network, refer to Figure 4.5. An open input-clamp is also part of the ohms converter circuit. The ohms voltage reference is a 7 volt temperature-stabilized zener, VR2. The 7 volt reference is buffered by the ohms current source generator op-amp AR1. The current through darlington transistor pair Q7 and Q8 is determined by R31 and R35. This network supplies 1 mA or 10 mA to the current-divider network. Relay K7 switches R35 in parallel with R31 to generate the 10 mA current source. The lower Ω source currents required for the 10K, 100K, 1000K and 10,000KΩ ranges are established by dividing the Ohms CURRENT SOURCE output. The current divider consists of R25, R27, R28, R29 and R33 and the division is controlled by range relays K2-K6. The ohms ranges, current sources and the range relays are shown in Table 4.4.

4.3.5.3 The open-input clamp protects the user's external input from voltage increases when the ohms terminals are not provided with a resistive load, or during range overload. The input open circuit voltage is clamped at −6 volts maximum by Q3, Q5 and transistor array U3. U3 clamps the base of Q7 to −30 volts thereby turning off the current source through Q8 during overload. CR2, Q8 and VR3 protect the current source from voltages applied at the input terminals.

**Table 4.5 - Ohms Range, Relay and I Source**

| RANGE | K2 | K3 | K4 | K5 | K6 | K7 | Ω SOURCE CURRENT |
|---|---|---|---|---|---|---|---|
| .1K | | | | | ▒ | ▒ | 10 ma |
| 1K | | | | | ▒ | | 1 ma |
| 10K | ▒ | | ▒ | | | | 100 μa |
| 100K | | ▒ | ▒ | | | | 10 μa |
| 1000K | | | ▒ | | | | 1 μa |
| 10000K | | | | ▒ | | | 100 na |

▒ ENERGIZED

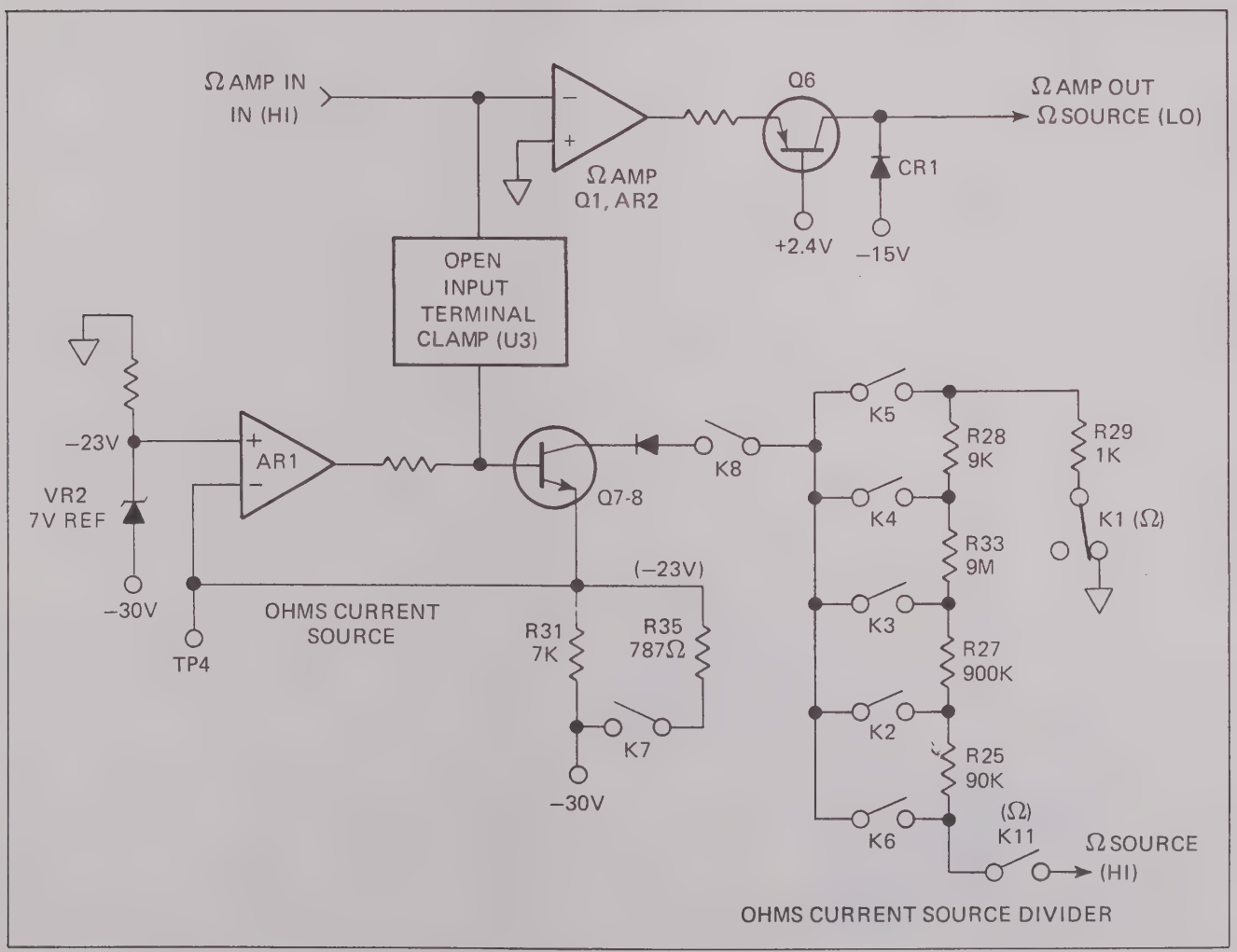



*Figure 4.5 - Simplified Ohms Converter*

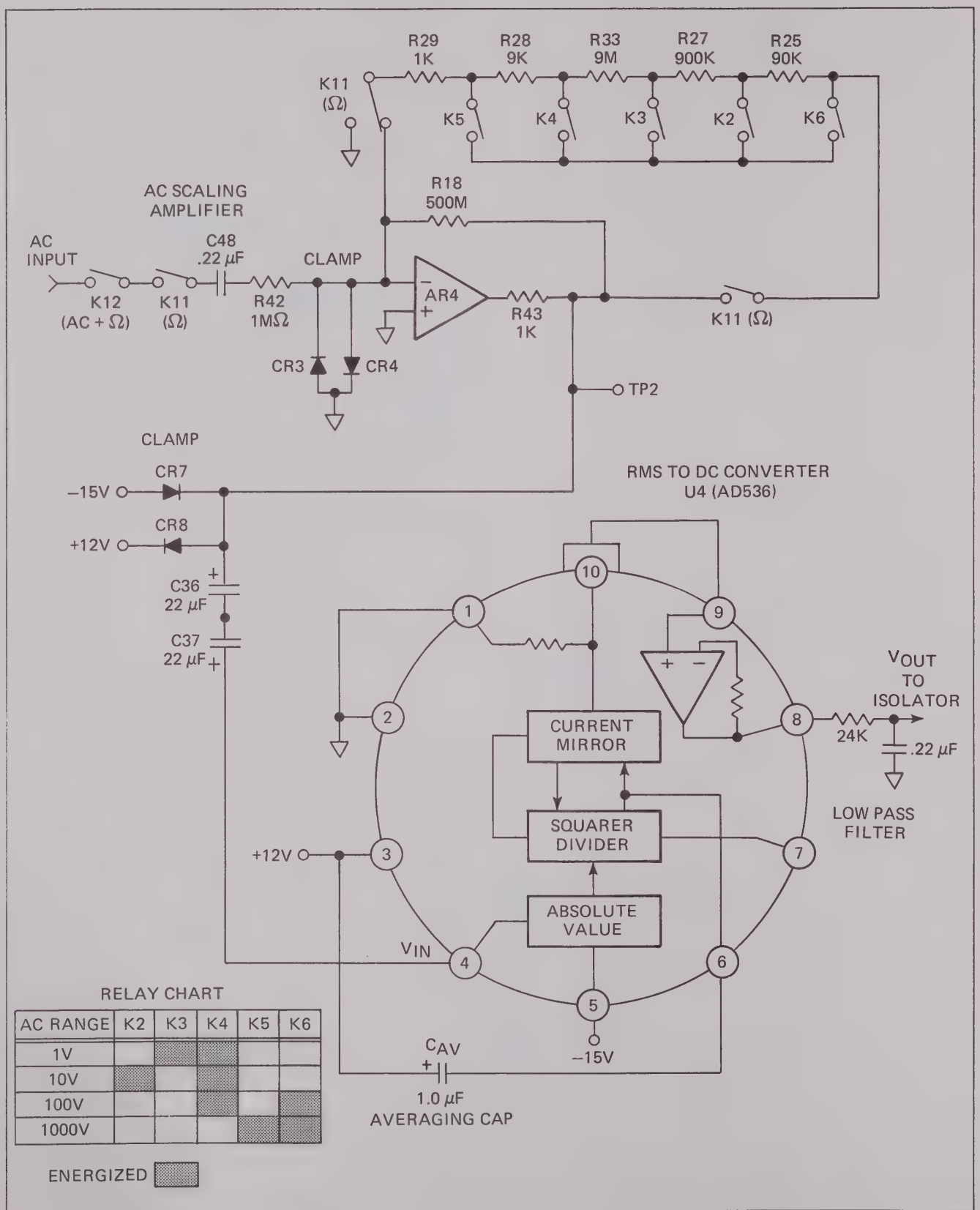



*Figure 4.6 - RMS Converter and Scaling Amplifier*

4.3.5.4 The Ohms Amplifier is an inverting operational amplifier consisting of Q1, AR2, Q6 and associated components. A simplified schematic is presented in Figure 4.5. The matched pair of FET's (Q1) is a differential amplifier stage driving operational amplifier AR2. The FET stage input is protected from overloads by series resistor R3 and transistors Q2 and Q4 connected as diode clamps. The output of AR2 is buffered and protected from high voltages applied to the input terminals while in the Ohms Function. Protection is provided by Q6, CR1 and VR4.

### 4.3.6 AC Function.

4.3.6.1 The AC Signal conversion hardware located in section two of the PCB assembly consists of RMS to DC converter U4, operational amplifier AR4, range selector relays K2, K3, K4, K5 and K6, range resistors R25, R27, R28, R29, and R33, complemented with other associated components.

4.3.6.2 The AC input signals are switched to input coupling capacitor C48, through the AC+Ω relay K12 (energized), and ohms relay K11 (de-energized). A simplified schematic of the AC Section is presented in Figure 4.6. The AC signal continues through C48, which blocks DC inputs to the Scaling Amplifier, to R42.

4.3.6.3 The scaling amplifier is an inverting op-amp with input resistor R42, amplifier AR4 and selectable feedback network to establish gain. Range relays K2, K3, K4, K5 and K6 select the feedback resistance for each range. The scaling amplifier supplies unity gain in the 1V range and attenuates the input signal in the 10, 100, and 1 KV ranges. The output from the Scaling Amplifier is 1 VAC for a full scale input in each range. The scaling amplifier feedback network and range relays serve a dual purpose; they are used in the OHMS Function also, to divide and select the current source output for each range. The relay chart shown in Figure 4.6 presents the relay states for each range selected.

4.3.6.4 The Scaling Amplifier input is protected from overload voltages by diode clamps CR3 and CR4. The scaling amplifier output and RMS to DC Converter input are protected from high voltage transients by current limiting resistor R43 and diode clamps CR7 and CR8.

4.3.6.5 The RMS to DC Converter is driven by the scaling amplifier output through the DC blocking capacitors C36 and C37. The RMS to DC Converter IC provides a true root-mean-square level of a complex AC signal, and gives an equivalent DC output. The RMS converter contains three major circuits on the chip to perform the AC to DC conversion. They are the Absolute Value circuit (active rectifier), Squarer/Divider, and Current Mirror circuit. The input voltage signal from the scaling amplifier is converted to a unipolar current by the Absolute Value circuit. The Squarer/Divider circuit, the Current Mirror circuit and the Averaging circuit combine to compute the RMS value of the converted input current. An external averaging capacitor ($C_{av}$ = 1 $\mu$F) and an internal 25 Kohm resistor form a low-pass filter. This filter effectively averages the Squarer/Divider output signal which drives the current mirror. The current mirror output is buffered and outputted at pin 8. The output signal passes through a single pole filter R12-C12, to remove any AC ripple content before routing the DC signal to the Isolator. The settling time for the converter is determined by the time constant which results from $C_{av}$, the averaging capacitor and an internal converter resistor.

4.3.6.6 The RMS Converter output is routed to the Input Attenuator and Isolator through the contacts of Ω relay K1 (de-energized) and AC + Ω relay K12 (energized). Attenuator relay K9 is energized in all AC ranges and does not attenuate the RMS Converter output which is applied directly to the Isolator input. The Isolator serves as a unity gain, high impedance buffer between the RMS Converter and the Digitizer.

## 4.4 QUANTIZED FEEDBACK A/D CONVERTER.

### 4.4.1 General.

4.4.1.1 The A/D Converter uses a quantized feedback (QF) conversion technique to convert the analog output from the Isolator to a BCD format for further processing and display.

4.4.1.2 The A/D Converter hardware is located in Section 3 of the PCB assembly. The converter consists of A/D Analog Processor (U11), Digital Counter and Control I.C. (U10), Measure/Zero (M/Z) switch U26, Input Buffer AR5, Auto-Zero Buffer AR3, Auto-Zero switch Q9, Digit Mode switch Q10, Voltage Reference VR1, and Opto-isolator drivers U9/U17. A simplified diagram of the Analog Processor and supporting external circuitry is shown in Figure 4.7 where designators and circled numbers relate to the A/D schematic at page 6-13. A block diagram of the A/D Digital Counter and Control is presented in Figure 4.8.

4.4.1.3 The A/D conversion is performed by two LSI circuits - a charge-balancing Analog Processor (U11) and a proprietary Digital counter and control IC (U10), that contains all the digital circuitry for the 'quantized feedback' system. The Analog Processor contains a bipolar comparator, bipolar integrating amplifier, buffer amplifiers and analog

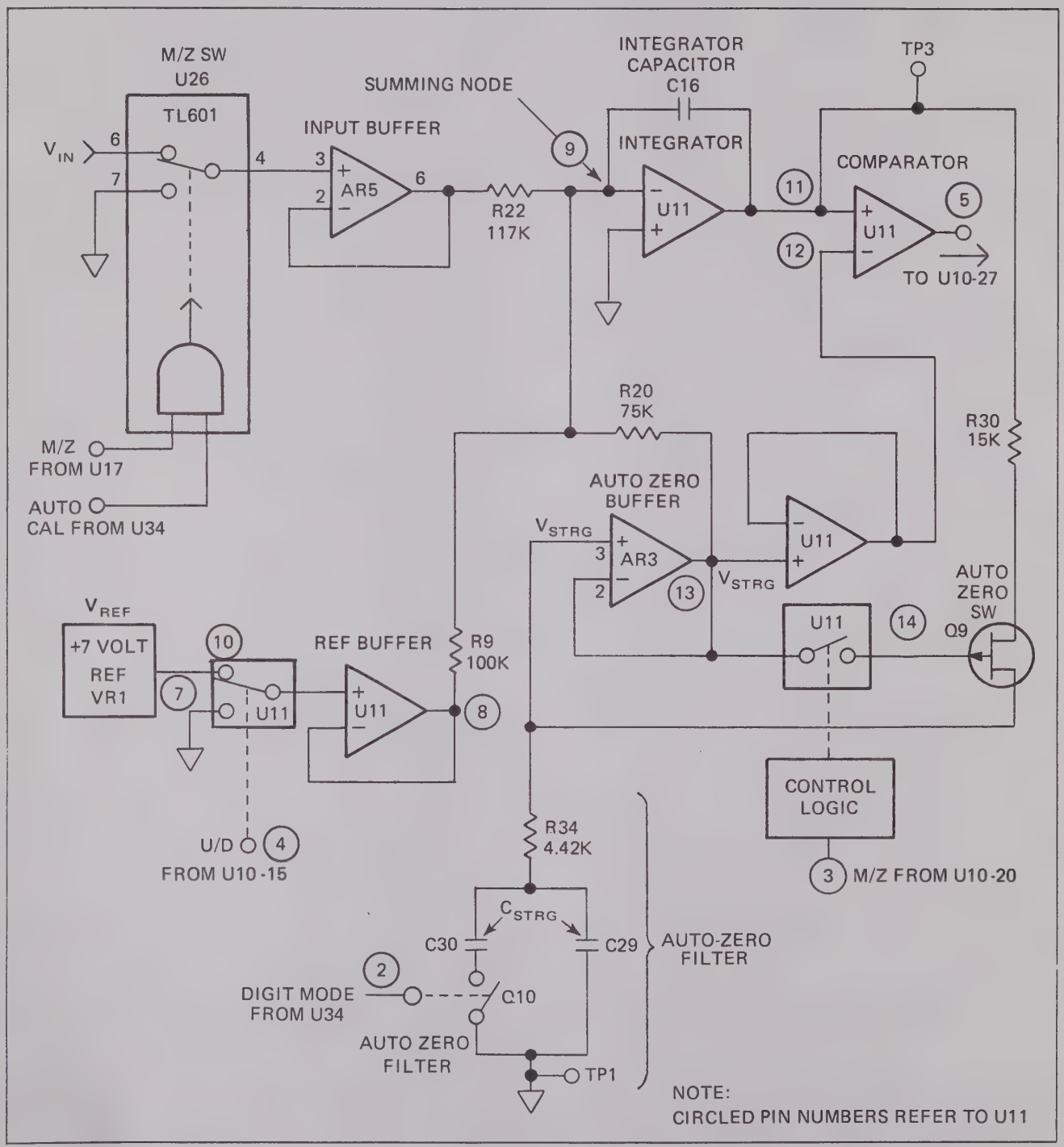



*Figure 4.7 - Simplified A/D Analog Processor*

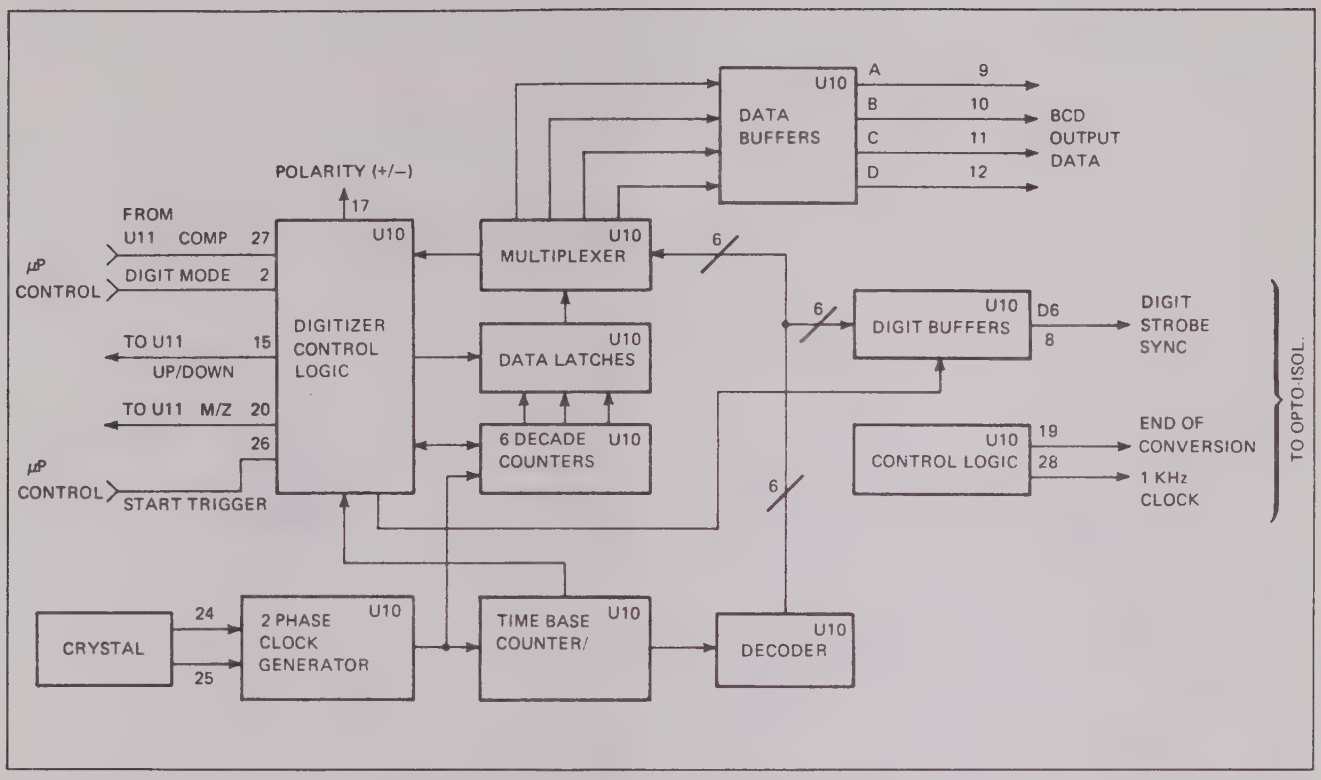



*Figure 4.8 - A/D Digitizer Counter and Control*

switches. External Buffer amplifiers AR5 and AR3, measure/zero (M/Z) switch U26 and auto-zero switch (Q9) are used to improve performance of the Analog Processor. The Digital Control I.C. is a synchronous digital processor and combines the time-base generation, counting, data multiplexing and random logic necessary to control the Analog Processor. A stable 7 volt reference voltage for the A/D converter is supplied by VR1.

## 4.4.2 Time Base Generation.

4.4.2.1 MEASURE/ZERO (M/Z) SIGNAL.

4.4.2.1.1 Basic timing signals for the A/D Converter are generated by the 2-Phase Clock Generator and Time-base Counter in U10. The Clock Generator, controlled by an external crystal, supplies a two-phase output at a 2.4576 MHz frequency (2.048 MHz in 50 Hz instruments) to the Time-base counter. In 60 Hz instruments operating in the 5-1/2 digit mode, the Time-base counter divides the clock frequency into sampling periods of 614,400 pulses (250 milliseconds). A period of 409,600 pulses (166.67 ms) is defined as the Measure Interval and 204,800 pulses (83.33 ms) as the Auto-zero interval. When operating in the 4-1/2 digit mode the Measure Interval is 16.67 ms and the Auto-zero period is 8.33 ms. The resulting measure/zero (M/Z) waveform, shown in Figure 4.9, is applied to the analog processor. When the logic level on the START TRIGGER line is held low, the M/Z waveform is generated continuously and the DMM is taking measurements continuously at a rate of 4 readings/sec (60 Hz instrument, 5-1/2 Digit mode) or 40 readings/sec (60 Hz instrument, 4-1/2 Digit mode). When operating the DMM in the Hold/Command (triggered reading) mode, a logic high on the START TRIGGER line holds the system in the Auto-zero mode. A negative going pulse on this line initiates one measurement cycle.

4.4.2.2 UP/DN CONTROL SIGNAL.

4.4.2.2.1 The up/down (U/D) control signal to the Analog Processor is also derived from the Time-base counter. This control signal has a period of 160 clock pulses. During the Auto-zero mode the U/D waveform has a 50% duty cycle (logic high for 80 counts and logic low for 80 counts). During the Measure interval the Digitizer Control logic examines the output of the comparator in the Analog Processor once each 160 clock pulses. If the comparator output is high, the UP/DN control will be high for 10 clock pulses and low for 150 clock pulses during the next 160 clock pulses. If the comparator output is low, the U/D control will be high for 150 pulses and low for 10 pulses. How the U/D control is used to control the Analog Processor is discussed in the following paragraphs.

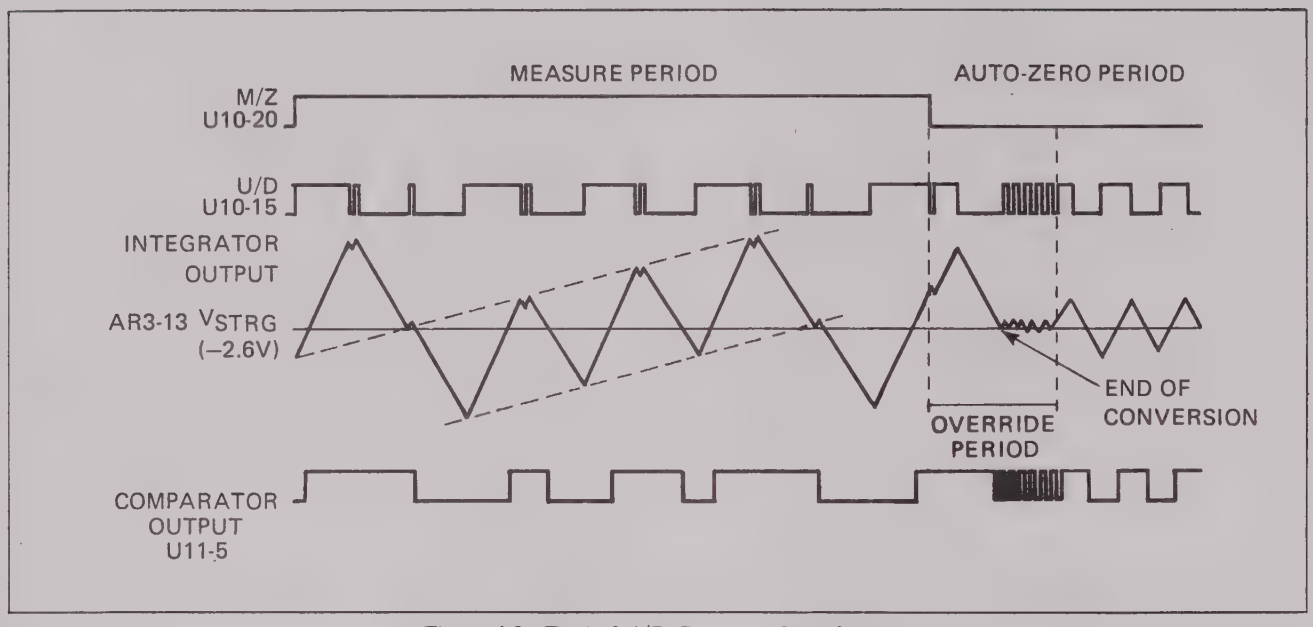



*Figure 4.9 - Typical A/D Converter Waveforms*

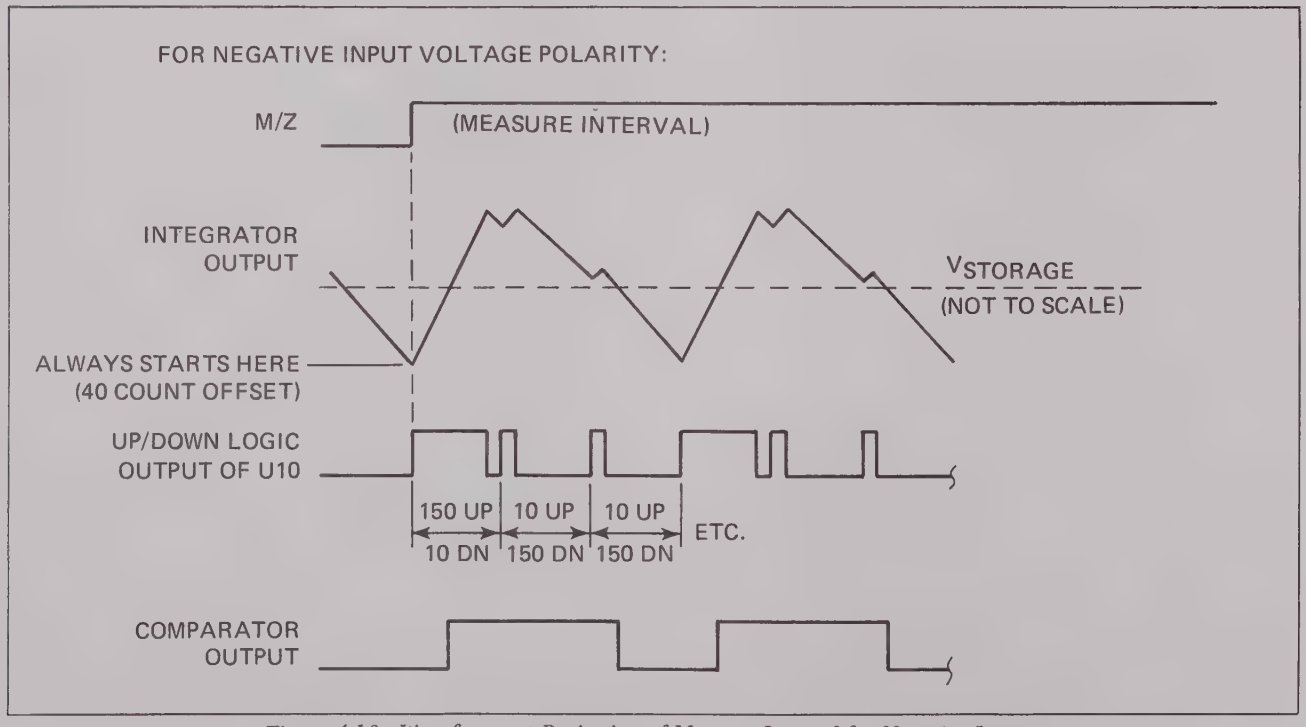



*Figure 4.10 - Waveforms at Beginning of Measure Interval for Negative Input*

### 4.4.3 Auto-Zero Interval.

4.4.3.1 Referring to Figure 4.7, during the Auto-zero (A/Z) interval the input of AR5 (Input Buffer) is switched from the Isolator output to analog common by M/Z switch U26. Auto-zero switch Q9 is enabled and connects the Integrator output to Auto-zero filter capacitors C29 and C30, and the input of Auto-zero buffer AR3. Both switches are controlled by the M/Z signal from the Digital Control IC, U10. The U/D control signal, with its 50% duty cycle, alternately switches the input of the Reference Buffer between Analog Common and the 7 volt reference, VR1. When the U/D control is low, the Reference Buffer output is equal to +7 volts; when the U/D control is high, the Reference Buffer output is zero. The Integrator input current (pin 9 of U11) is a summation of currents from the Input Buffer, Reference Buffer and Auto-Zero Buffer through resistors R22, R9 and R20 respectively. The average current through R9 is equal to one-half the Reference Voltage divided by the value of R9, $(\frac{VREF}{2R9})$, because the reference current is flowing through R9 half of the time. The Auto-zero Buffer supplies a current through R20 equal to the voltage on the Auto-zero Filter capacitors divided by R20. The output of the Integrator is applied to the Auto Zero Filter capacitors C29 and C30 through R30, Q9 and R34, and the capacitors charge to a voltage proportional to the average value of the input currents (approx. −2.6V). This voltage is negative because of the inverting action of the Integrator. C29 stores the Integrator output in the 4-1/2 Digit mode, and C30 is switched in parallel by Q10 when the 5-1/2 Digit mode is selected to provide a longer time constant. Note that the voltage, Vstrg, at the output of AR3 is also applied to one input of the comparator through an internal Buffer Amplifier. This voltage remains on the comparator during the Measure Interval and establishes the comparator threshold at Vstrg (−2.6V).

4.4.3.2 The loop around the Integrator reaches equilibrium when the sum of the currents into the Integrator summing node equal zero. The voltage on the Filter capacitors (Cstrg) remains at approximately −2.6V when the Auto-zero switch Q9 opens at the end of the AZ interval because of the high input impedance of AR3. The BCD counters in U10 are also reset to zero by the last clock pulse of the Auto-Zero interval.

### 4.4.4 Measure Interval.

4.4.4.1 At the start of the Measure Interval; (a) the M/Z control goes high, switching the Isolator output to the Input Buffer AR5 through M/Z switch U26, (b) Auto-Zero switch Q9 is switched OFF, disconnecting the Integrator output from the Auto-Zero Filter capacitors, (c) U/D control is high, switching the Reference Buffer input to Analog Common, and (d) the Integrator output is slightly more negative than Vstrg (see Figure 4.10). At this time, the only inputs to the Integrator are Vstrg and the input signal from the Isolator (buffered by AR5). With only these two inputs, the Integrator output will always move in a positive going direction, independent of the polarity of the signal from the Isolator. As the Integrator output moves away from Vstrg, the comparator senses the output of the Integrator and compares it to Vstrg on the other Comparator input (pin 12 of U10). The comparator output transmits the sense of deviation of the Integrator output from Vstrg to the Control Logic circuits in U10. The Control Logic circuit generates the UP/DN control signal as described in paragraph 4.4.2.2 and shown in Figure 4.9 and 4.10. The effect of the two duty cycles (10 up, 150 down or 150 up, 10 down) is to source or sink a net 140 clock pulses of charge to integrator capacitor C16, thus driving the Integrator output toward Vstrg and accumulate a net 140 counts in the up/down counters. The charge is supplied by the current through R9 from the buffered Reference voltage. Charge is added to C16 when the Reference Voltage is applied to R20 and subtracted when the Reference voltage at the output of the Reference Buffer is zero. The net amount of charge required to keep the Integrator output at Vstrg during the Measure Interval is measured by the Up/Down Counter in the Digital I.C. The BCD count at the end of conversion equals the number of charge parcels necessary to cancel the input voltage and the resulting digital count is proportional to the analog voltage.

### 4.4.5 Over-Ride Interval.

4.4.5.1 At the end of the Measure Interval the total counts accumulated by the counter will be a multiple of 140. A residual voltage on Integrator capacitor C16 represents the remaining unresolved portion of the input. This voltage is cancelled and the corresponding counts accumulated during

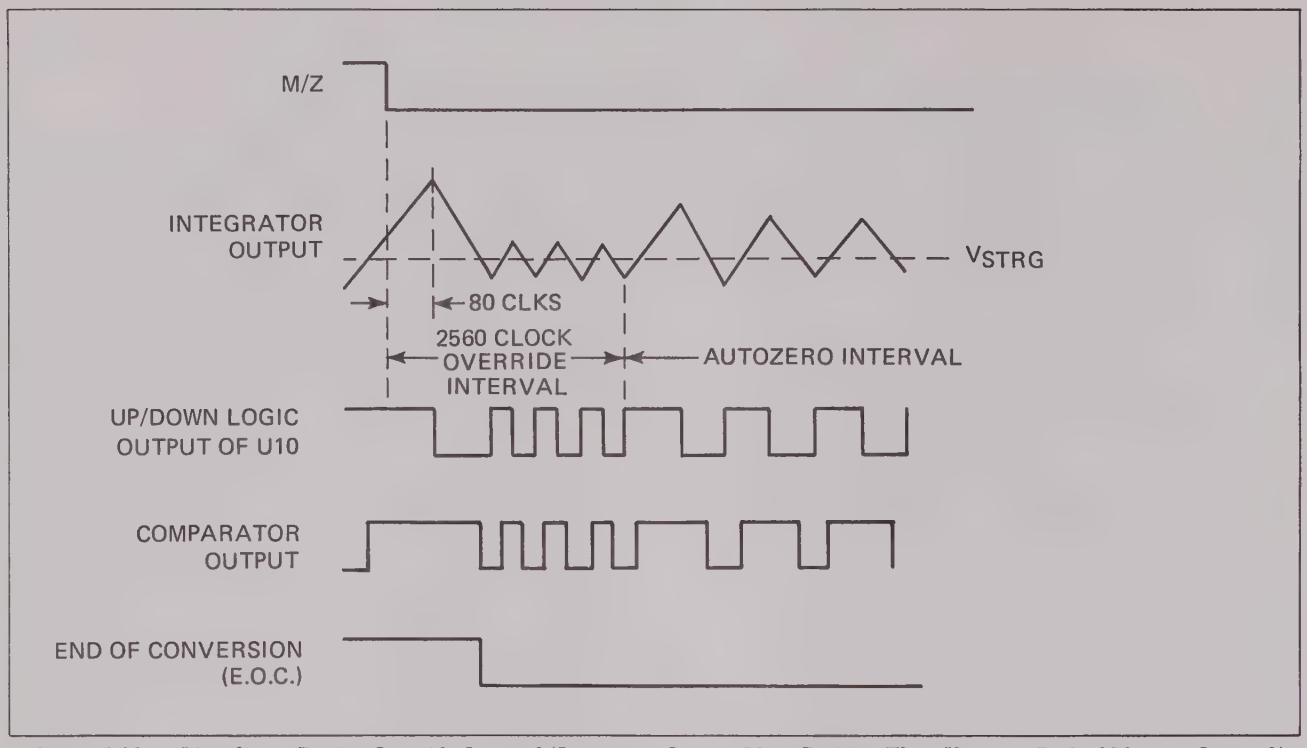



*Figure 4.11A - Waveforms During Override Interval (Integrator Output More Positive Than $V_{strg}$ At End of Measure Interval).*

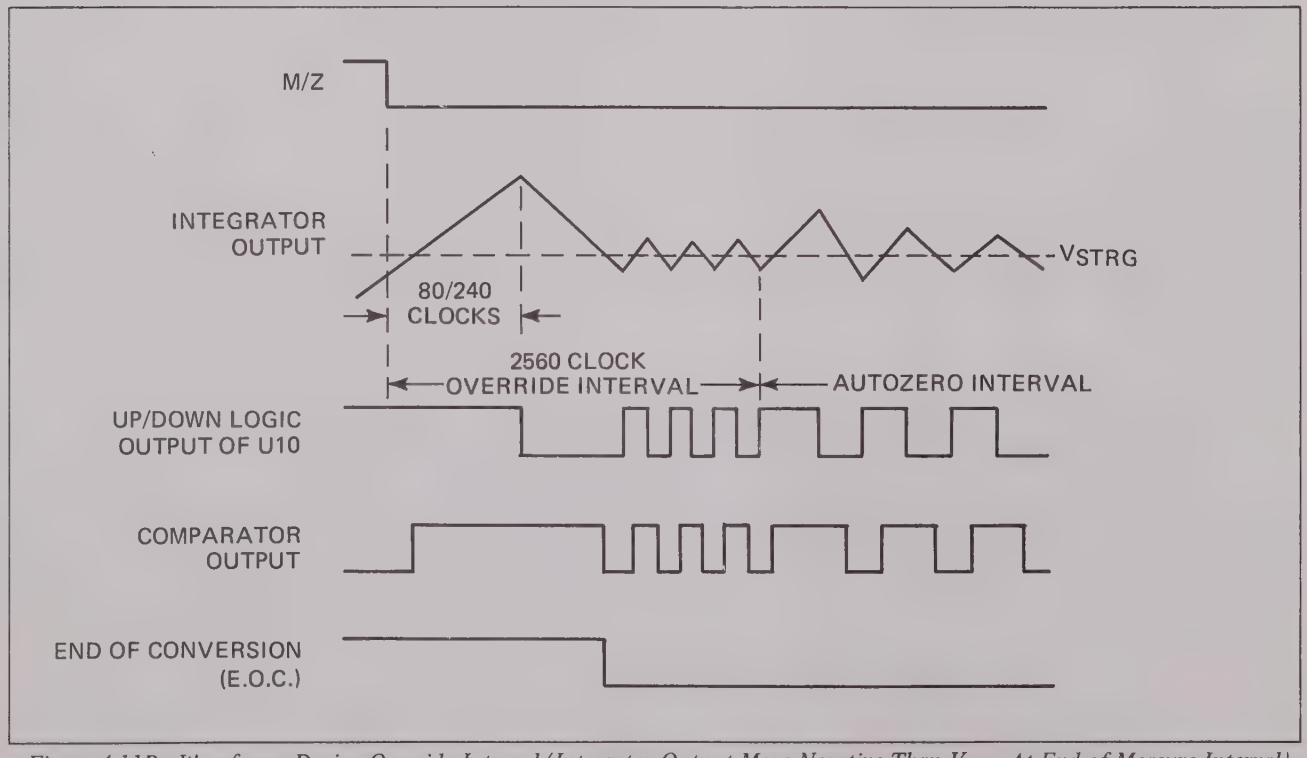



*Figure 4.11B - Waveforms During Override Interval (Integrator Output More Negative Than $V_{strg}$ At End of Measure Interval)*

an interval at the beginning of Auto-Zero called the "Override Interval". The Override Interval is a fixed 2560 counts long (1.04 ms in a 60 Hz instrument). During the Override Interval the input of AR5 (Input Buffer) is switched to ground through M/Z switch U26, but the AZ Filter remains disconnected from the Integrator output (Q9 is OFF). When the Measure Interval ends, the Integrator output will be either higher or lower than Vstrg. Override Interval waveforms for both conditions are shown in Figure 4.11A and B.

### 4.4.6 Digitizer Counter & Control Output.

4.4.6.1 The 4 bit BCD data stored in the data latches of U10 are multiplexed and routed through the opto-isolator drivers U9 and U17, and presented one digit at a time to the microprocessor control section of the DMM.

4.4.6.2 The A/D output control signals are:

a) END OF CONVERSION: Advises μP that A/D conversion is completed and that a reading is ready.

b) 1 KHz: Synchronizes data transfer between A/D and μP.

c) DIGIT STROBE SYNC D6: Advises μP when the sixth BCD digit is being transmitted.

d) POLARITY: Polarity information passed on to the μP (+ or – input).

## 4.5 DIGITAL THEORY OF OPERATION.

### 4.5.1 Digital Hardware Description.

4.5.1.1 The DMM's digital control centers around U35, (Dwg. on page 6-28), a 6802 microprocessor which executes the program contained in ROMs, reads data from various locations throughout the DMM and stores data to RAM and to various hardware locations throughout the DMM. The microprocessor executes the ROM program based on these data, performs calculations, and makes decisions to control all the functions described in Section 3 of this manual.

4.5.1.2 The hardware locations contributing data to the microprocessor are the Digitizer (via opto-couplers OCI1 and OCI2), the keyboard on the front panel, and through the GPIA (U44) which passes commands from the 488 bus to the μP. This group is located at Sections 5, 6, 7, 8 and 9 as shown in Figure 4.1.

4.5.1.3 In turn, the microprocessor outputs processed data to the GPIA and LED display. The μP also sends control information to the Digitizer and the analog hardware via opto-isolator OCI3. The Figure 4.12 graphically presents the hardware network controlled by the microprocessor. The schematic drawing on page 6-19 listed in Section 6 presents the coded designators that input and output to/from the microprocessor through the opto couplers.

### 4.5.2 The Microprocessor Section.

4.5.2.1 The microprocessor section (MPU) located in Section 6 on the motherboard consists of the microprocessor U35, with program memory IC's U27, U28, U29 and U30, address decoders U14 and U15, interrupt control hardware U2, U6 and U20, and non-volatile memory system U43, U42, VR12, BT1 and Q21. The complete schematic drawing is listed in section six pages 6-15 and 6-17.

4.5.2.2 When power is first applied to the microprocessor (μP), the R76-C75 time constant on the μP's RESET input (U35-40) holds the μP in reset long enough for the power supplies and clock to stabilize, then reset goes high (HI) enabling the start-up routine.

4.5.2.3 The DMM system clock is generated by the μP combining internal components with external components connected to pin U35-38 and U35-39 comprising of a 3.579 MHz crystal Y1 and C73-C76 components. The μP divides this frequency by four then outputs at pins U35-37 as 'E' the system clock of 895 KHz (approx.) for all μP bus components.

### 4.5.3 Program Memory.

4.5.3.1 The entire program memory for the μP resides in ROM's U27 through U30. IC's U27, U29, U28 and U30 are connected so that each can hold a 2Kx8 model 2716 EPROM or U29 and U30 can be omitted and U27 and U28 can each contain a 4Kx8 ROM. The μP directs other hardware locations dedicated to specific memory assignments as the Non-Volatile-Memory; GPIA and Digitizer.

### 4.5.4 Address Decoding.

4.5.4.1 The IC's U14 and U15 comprise the address decoding hardware used by the μP. The inputs to the address decoders are various address lines from the μP as well as other control lines. Each decoder has 8 normally high outputs, AY0 to AY7 and BY0 to BY7 which are used as 'Chip selects' for various hardware throughout the DMM. When the μP places an address on its address bus, U14 and/or U15 decode this address and supply the required chip select to the selected component which is being addressed by the μP.

4.5.4.2 The outputs of U14 are not gated internally with the clock, therefore the negative pulse widths may vary from 900 to 1200 ns. The outputs from U15 are internally gated

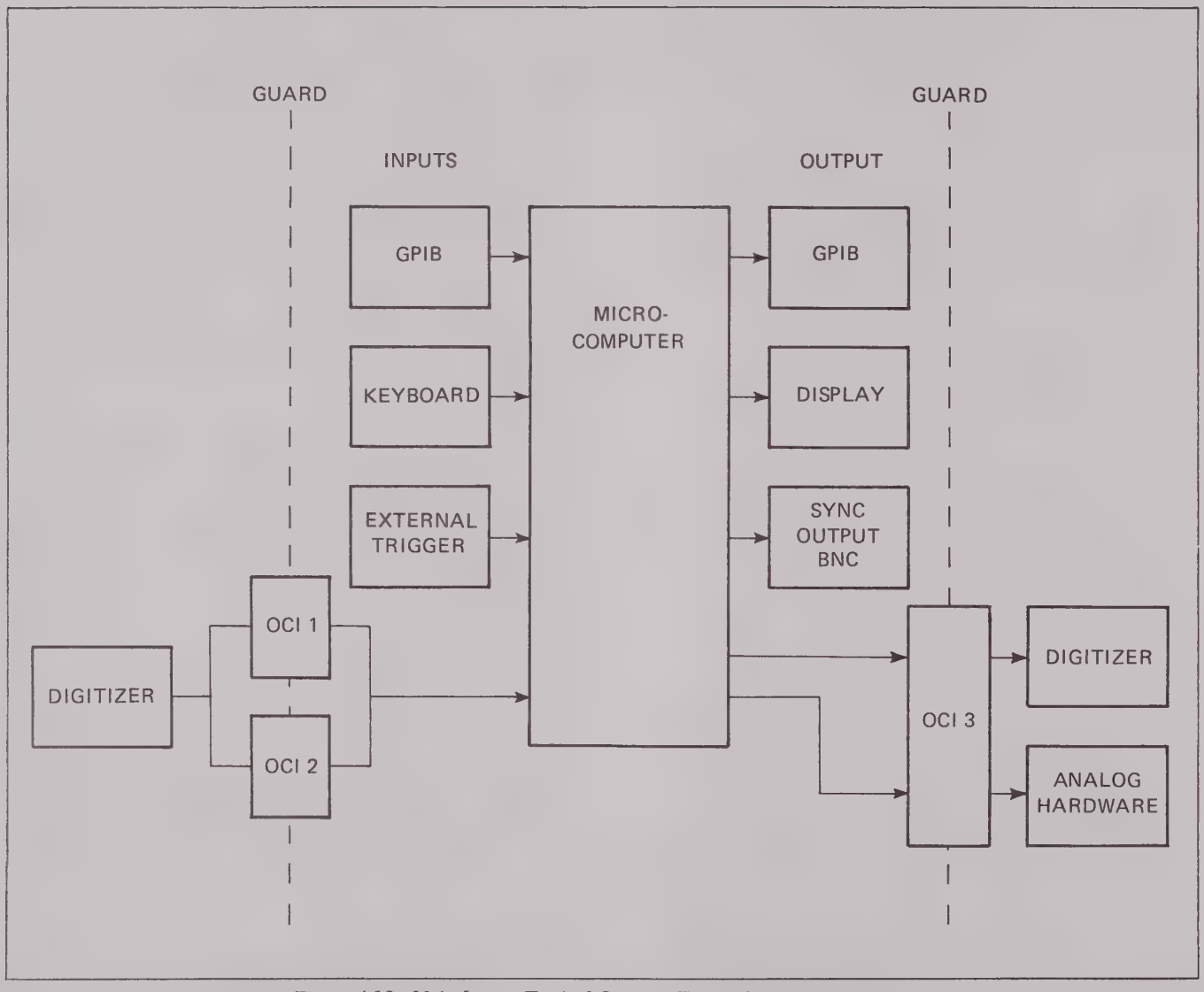



*Figure 4.12 - Main Inputs To And Outputs From The Microcomputer*

with the system clock E, therefore the outputs are practically a consistent pulse of 516 ns.

### 4.5.5 Non-Volatile Memory.

4.5.5.1 The DMM uses a non-volatile memory (NVM) to store calibration (CAL) constants for later recall. The constants are stored during laboratory calibration and are recalled from the NVM whenever the DMM Function or Range is modified. The NVM is comprised of U43, a CMOS RAM, and Quad Nand gate U42 along with a three volt lithum battery BT1, a sharp knee zener VR12, a constant current regulator Q21 and steering diodes CR17 and CR21.

4.5.5.2 During normal DMM power-on operation, the NVM circuit receives 9 volts unregulated from the digital power supply. The current from the unregulated supply is regulated by Q21, a FET connected as a constant current source. This constant current (normally 7-13 mA) forward biases diode CR17 and causes VR12 to zener at approximately 5.3 volts. The voltage across VR12 reverse biases CR21 to prevent battery charging, and also supplies a regulated voltage to U42 and U43.

4.5.5.3 During the AC power-off periods, battery BT1 causes CR21 to forward bias so that approximately 2.5 volts is available to power U42 and RAM U43. This same voltage reverse-biases CR17 which prohibits battery flow into the power supply. When in this mode, approximately 2.5V is across VR12, the sharp knee zener. Because of its sharp knee feature, VR12 draws insignificant current, approximately 3 μA at room temperature.

4.5.5.4 A hardware Write-Protect circuit prevents accidental modification of the contents of RAM U43 during normal operation, power up or down cycles and power brown-outs. This circuit is comprised of W/R control gate U42, a 10K pull-up resistor R79 and CAL-switch S1 which is located behind the front panel, refer to Figure 3.1-54 for illustration. When the switch is open, pin 14 on RAM U43 constantly remains HI, which prevents any RAM "write" operation so that its contents cannot be modified. When the CAL switch is depressed, the μP can drive the WRITE pin on the RAM LO, enabling the U43 memory modification.

### 4.5.6 Interrupt Control Hardware.

4.5.6.1 The interrupt signals to the μP are processed by the interrupt control hardware consisting of dual Flip-Flop U2, two NAND gates in U6, and 1/6th of inverter U7.

4.5.6.2 The interrupts from the Digitizer and GPIA are NANDED by U6-4, 5, 6 and inverted by U7-3, 4, to appear on the interrupt request (IRQ) pin of the μP U35-4. This ANDing either from the Digitizer via the lower half of U2 or an interrupt from the GPIA via pin U6-5 will cause an interrupt to be gated to the μP.

4.5.6.3 External Triggers from the rear panel BNC connector J202, drive pin U6-2 LO then are inverted by U6 causing a positive edge at pin U2-3. This trigger clocks a LO at pin U2-5 which will cause a non-maskable interrupt (NMI) to occur at the μP pin U35-6. This NMI will cause the μP to cease its present software calculations and act upon the external trigger. The number of triggers arriving at the μP determine whether the μP will re-enable the external trigger or not. Enabling the external trigger occurs by the μP pulling pin U2-4 LO momentarily. If this is done, that portion of U2 will be set so that a second external trigger can be received by the hardware. If this is not done by the μP as would be the case when many external triggers are received rapidly, then pin U2-5 will remain in a LO state until the μP decides to pull pin U2-4 momentarily LO to set that half of U2.

4.5.6.4 The Analog Interrupts which originate from the analog side of the DMM are used to clock the lower half of U2. These evenly timed interrupts occur every 6 ms (every 7.2 ms in 50 Hz DMM) and clock the lower half of U2 at pin 11. This causes pin U2-9 to go LO, which causes the μP's IRQ input to go LO. When the μP responds to this interrupt, it reads the output of U20, a hex three-state buffer. Since pin U2-9 is connected to pin U20-10, the μP can determine if the IRQ originated from U2 by examining the D7 output (pin 9) from U20. If U2-9 is found to be low, the μP applies a negative pulse to pin U2-10, which removes the IRQ.

4.5.6.5 The interrupts which occur approximately every 6 ms as a result of the clock on pin U2-11 are used by the μP to sequence the scanning of the keyboard and to check whether certain front panel LED's need up-dating. If problems are observed in any of these areas, then a correct clock into pin U2-11 should be verified.

### 4.5.7 The Hardware Control Codes.

4.5.7.1 The hardware which brings information from the analog section of the DMM to the digital section is presented in schematic drawing on page 6-19.

4.5.7.2 The eight signals entering from the left edge of schematic on page 6-19 are brought in from the analog section of DMM through the opto-isolator couplers OCI-1 and OCI-2 to the digital three-state hex buffer U16. Four of these are multiplexed (MUX) BCD data lines A, B, C, D lines. Via these lines, 6 digit MUX BCD data is brought across guard

through the opto-isolators. The other four lines are single lines designated as follows:

a) POLARITY: This line indicates the polarity of the most recently completed reading.

b) 1 KHz: This lines supplies a 1 KHz frequency (0.833 KHz in 50 Hz DMM). The high-low transitions of the 1 KHz waveform are monitored by the μP to determine when a new BCD digit is being MUX across guard on the A, B, C, D lines.

c) DIGIT STROBE SYNC D6: This line is used to generate real-time interrupts to the μP which was described previously and to help MUX the sign (polarity) bit into the μP.

d) EOC: (END OF CONVERSION) This line changes state when a new reading has been completed. After crossing guard the EOC line is buffered by TTL Schmitt inverter (sections of U7) and is used to clock the input of the dual F/F at pin U8-11. When the F/F is clocked, the output pin U8-9 goes HI. This high output is read by the μP and indicates to the μP that a new reading is ready. The buffered output of the opto-isolator also goes, via U7 and U6 TTL buffer, to the display board and is used to drive the "sample" LED. Refer to Figure 3.1-56 for the sample LED location.

4.5.7.3 When operating on 5 1/2 digit mode, the μP spends considerable time waiting for a new reading to become available for process and display. It determines when a new reading is available by reading pin U8-9 via U13, the keyboard three-state hex buffer. When the μP reads U13-3 HI, it then knows that a new reading is available and it begins to read the six digits which are constantly MUX across guard through opto coupler OCI-2. The μP reads the MUX BCD pulses and other control lines through U16 a three-state hex buffer.

4.5.7.4 A typical set of waveforms are presented in Figure 4.13 as they would appear to the μP while reading the MUX BCD data from the analog section, crossing guard, to the input of U16. The μP uses the positive edge of the 1 KHz signal to indicate when it should read the next nibble of BCD data from U16 inputs. The μP uses the DIGIT STROBE SYNC D6 signal to indicate when the most significant digit is MUX across guard.

4.5.7.5 The LO DIGIT STROBE SYNC D6 signal also causes the "sign" bit to be substituted in place of the D bit at U16's input. This switching of the sign bit in place of the D bit is done via the wired OR connection between the open collector outputs of OCI2 pin 10 and OCI1 pin 15.

### 4.5.8 Analog Control Registers.

4.5.8.1 The analog control hardware is housed in sections 4, 5, and 6 on the motherboard. The principal schematic on page 6-11 presents a relay operation chart and circuit details. Outguard portions of the circuit are shown on page 6-19.

4.5.8.2 The analog control system is comprised of a 4 bit latch U32, two shift registers U33 and U34, two relay drivers U18 and U19, relays K1 through K13, Schmitt trigger U25 and fet driver U36, as shown in Figure 4.14.

4.5.8.3 The μP program controls the digitizer, function, and range relays through 3 registers, 2 of which U34 and U33 are located on the analog side of guard, with the third U32, located on the digital side of guard.

4.5.8.4 U32 is a 4 bit latch which is loaded from the μP's data and address bus. The output from U32 is used to load registers U34 and U33 as well as trigger the digitizer shown on schematic on page 6-13.

4.5.8.5 U34/U33 REGISTER LOAD.

4.5.8.5.1 The DMM's function, range and/or integrate time can be modified as a result of keyboard inputs, GPIB commands, or autorange. When this occurs, a new relay drive bit pattern is determined by the μP. This pattern is then shifted across guard one bit at a time. The timing of the drive bit pattern is shown in Figure 4.15, the Register Load Timing diagram.

4.5.8.5.2 The first bit of this pattern, along with other control signals is latched into U32 from the μP's data bus and address bus. After propagating through the relatively slow opto coupler OCI-3, the data bit appears at the 'D' input of U34, along with a LO signal at U34's clock input. The microprocessor then stores the first bit to U32 along with other control signals that after progating through the opto-coupler, the first data bit remains at U34's 'D' input along with a "HI" signal at U34's clock input, which causes the first data bit to be shifted into U34. The above sequence is repeated until all 16 bits have been shifted into U34 and U33, which requires about 20 milliseconds.

4.5.8.5.3 After shifting all 16 bits into U34 and U33 the μP then strobes the shifted bits into the output registers of U34 and U33. To do this the μP stores a control bit pattern to U32 which propagates through OCI-3 and places a high level on U34-1 and U33-1. About 1 ms later, the μP removes this signal.

4.5.8.5.4 The output bits from U34 and U33 then energize relays via the open collector drivers U18 and U19, control Isolator gain via U36, or control the digitizer.

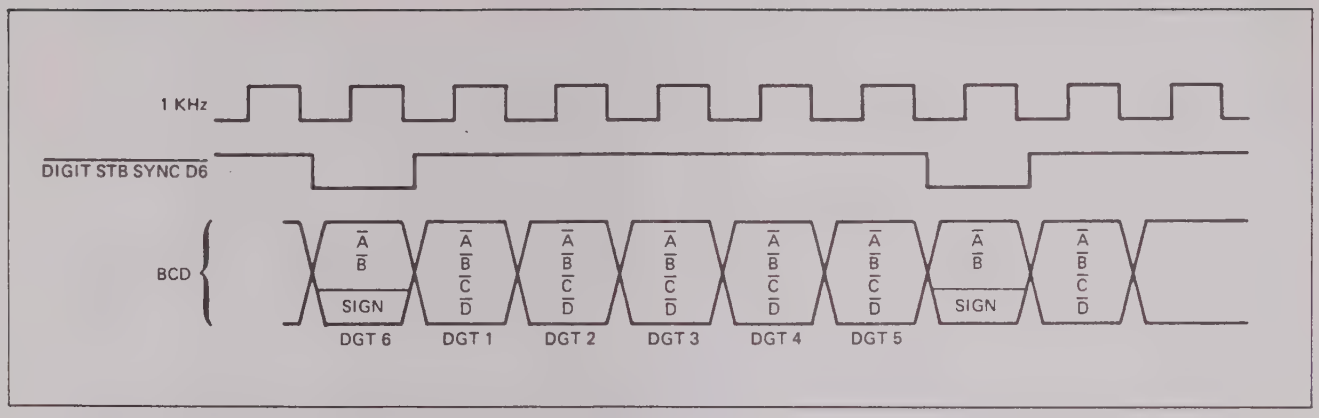



*Figure 4.13 - Typical Waveforms From Across Guard As Seen By µP Via Inputs On U16*

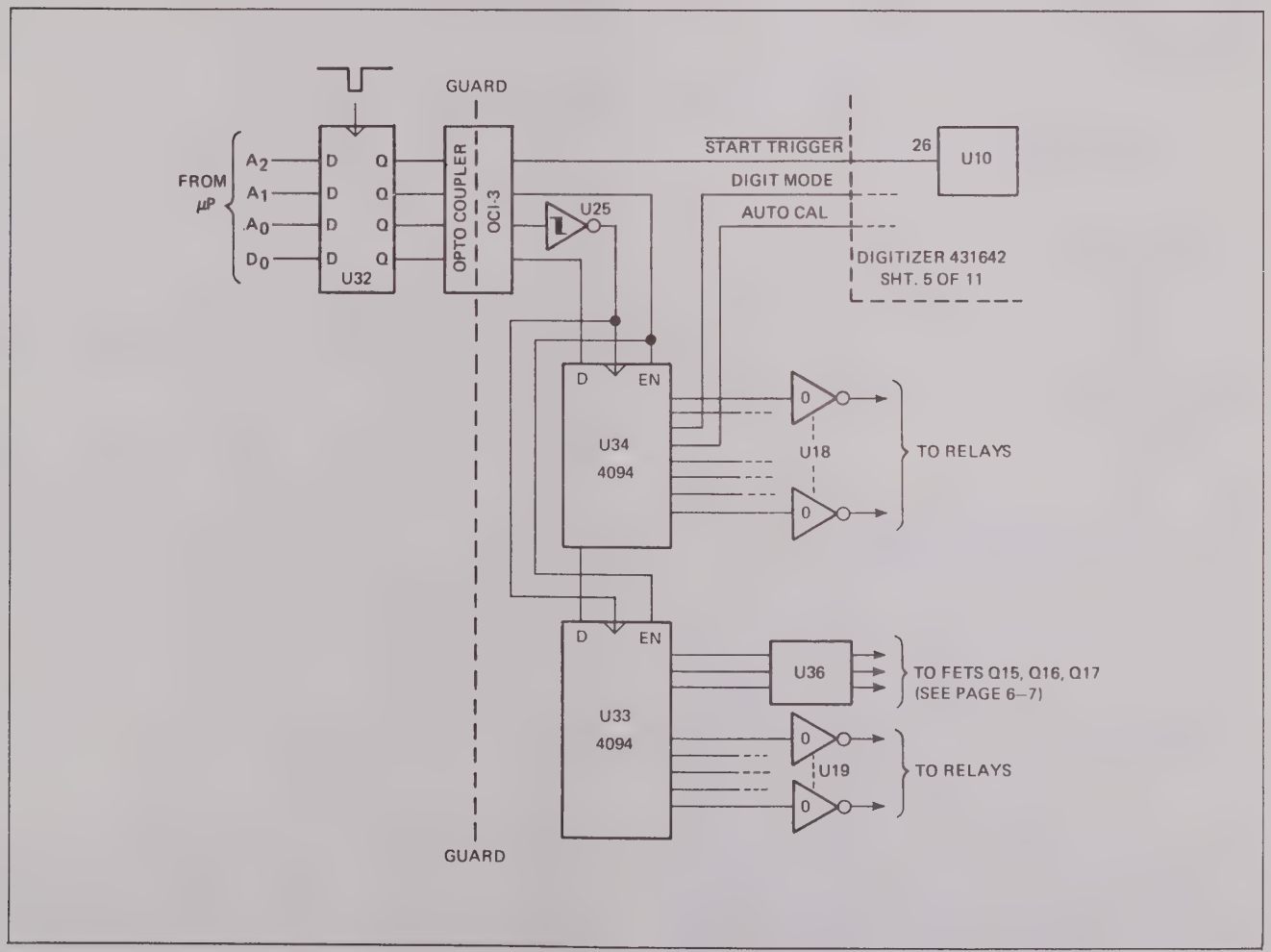



*Figure 4.14 - Analog Control Registers*

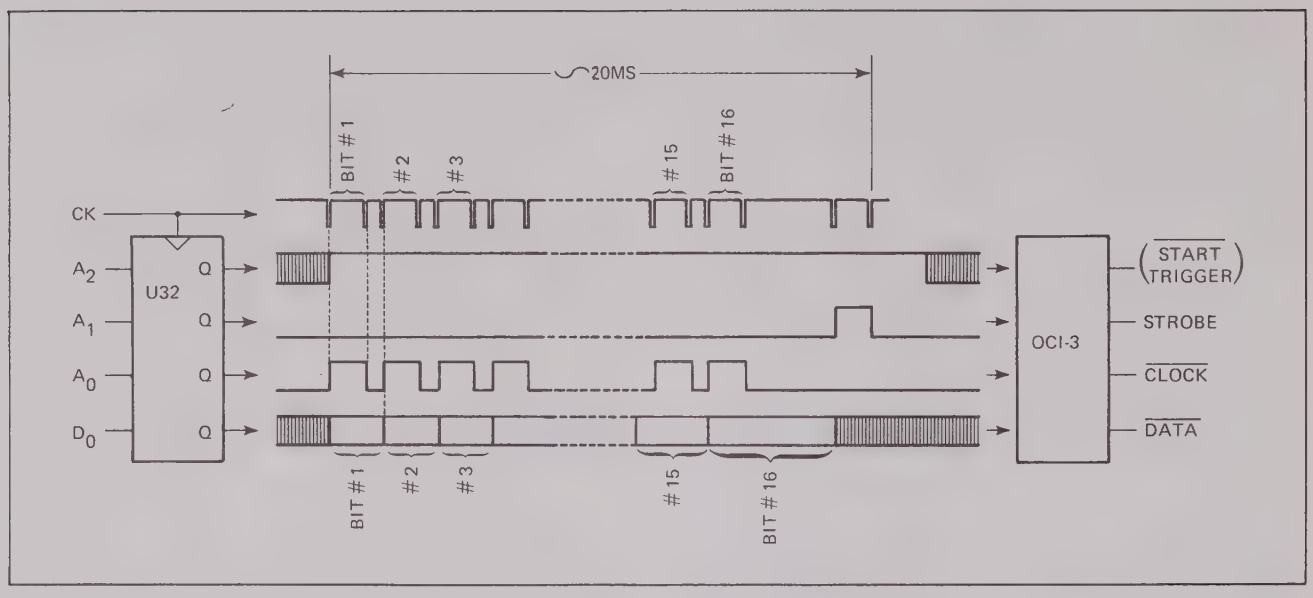



*Figure 4.15 - Register Load Simplified Timing Diagram*

4.5.8.6 DIGITIZER TRIGGERING.

4.5.8.6.1 When the μP requires a reading, it loads U32 with address line A2 LO. This then appears at U32's output, propagates across guard, and places a low level on pin 26 of U10 (digitizer drawing on page 6-13) to cause a read cycle.

4.5.8.6.2 When in the hold mode and at other times, the microprocessor waits for verification of a digitizer trigger by watching for a LO on pin 10 of U13, the keyboard buffer on page 6-23.

4.5.8.6.3 When operating in the "track" mode, (internal trigger) the μP leaves a LO on U10 pin 26 almost all the time in order to cause continuous triggers.

### 4.5.9 Keyboard Theory of Operation.

4.5.9.1 The DMM's keyboard is located on the display PCB whereas the associated ICs located on the motherboard; referred to as section 4 on the sectional chassis layout and detailed on schematic drawings on pages 6-3 and 6-23.

4.5.9.2 The keyboard circuitry consists of U5, an open-collector inverter used to buffer the μP's address lines which drive the N, M, L, H, K, and J columns of the keyboard. The keyboard buffer U13 is a three-state buffer connected so that the μP can read the signal from the keyboard rows T, R, U, and S. The pull-up resistor network Z2 pins 3 through 6 ensures that the μP will read a HI from U13 if its inputs become open, a condition that exists when no key is pressed. The chip select for U13 is DSPE, which is the same chip select for U12. This chip select originates from the NAND gate output U6-8. See paragraph 4.6.3.1 for further explanation.

4.5.9.3 The OPERATION is described as follows. When the μP must determine if any key is pressed, it reads from U13 while address lines A0-A5 are high. The ones on A0-A5 lines propagate through U5 and appear as zeros on N, M, L, H, and J columns of the keyboard as shown in Figure 4.13. When a key is pressed, the μP will read a zero on one of the row outputs through U13, the remaining rows will read ones. When a zero does appear, the μP then scans each keyboard column one-at-a-time by reading from U13 with only one of the lines A0-A5 high and others low, until the proper column has been driven low, and that a zero once again appears in the read from U13. Once this occurs, the μP suspends further keyboard scanning and processes the key in software.

## 4.6 DISPLAY BOARD.

### 4.6.1 Display Hardware.

4.6.1.1 The display hardware is configured on the motherboard as well as on the display board. The LSI Display Controller and Driver U12, 6-bit Range Latch U1 buffers U5, U53, U54 and U55 are located on the motherboard. The display PCB contains the 7-segment LED read-outs DS1 through DS7. Function-Range-Status LEDs and brightness-control current-limiting resistors. This group occupies section 9 on the chassis.

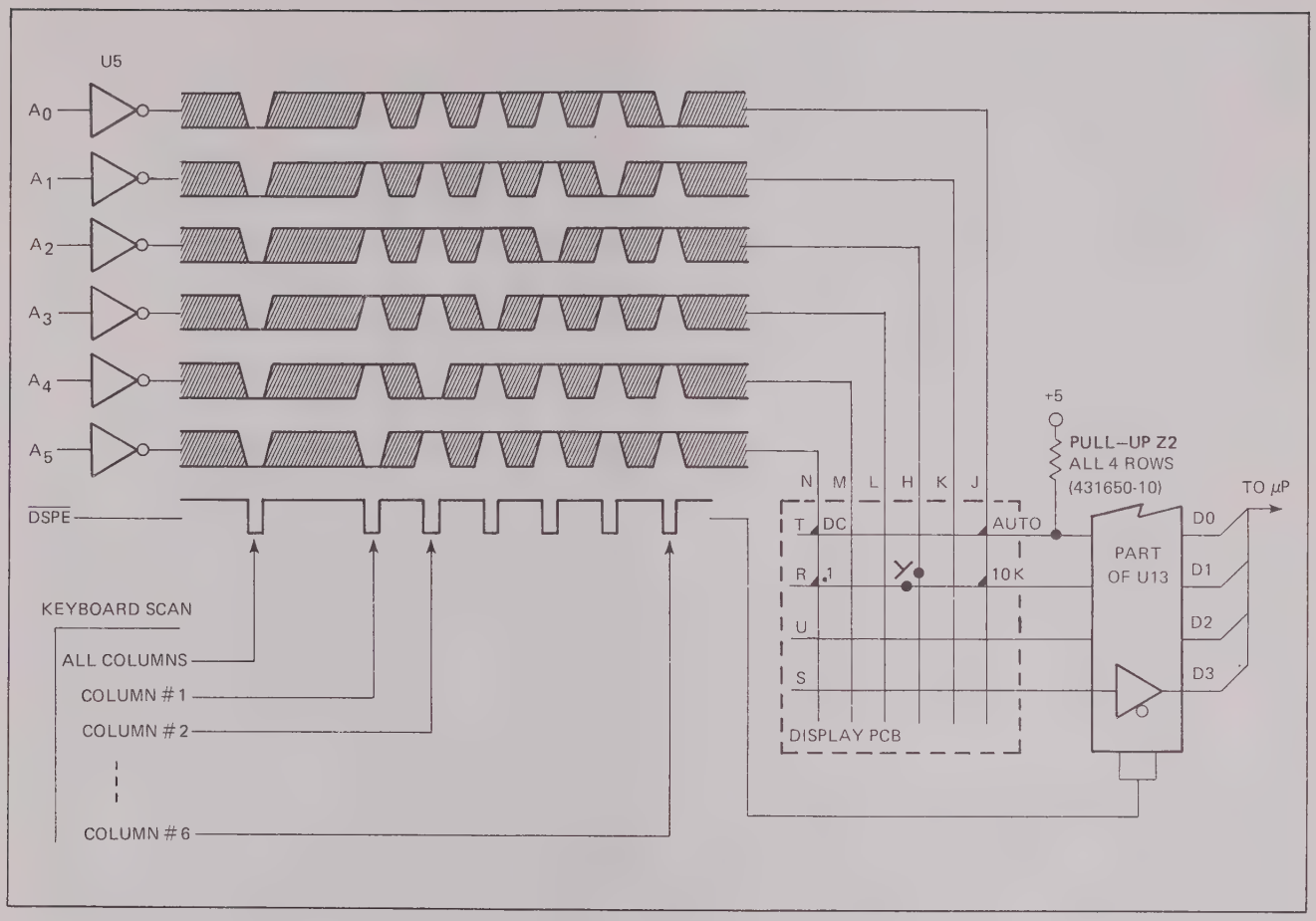



*Figure 4.16 - Keyboard Block and Timing Diagram*

### 4.6.2 Display Description.

4.6.2.1 The front panel LEDs are controlled by U12 and U1 through the μP. U1 is a 6-bit latch which is loaded from the data bus by the μP. The outputs of U1 drive 5 range annunciator LED's and the 'RI' LED. The display configuration is presented in the block diagram Figure 4.17. This drawing merges the motherboard and display board components to give an overview of the display schematics on page 6-3 and the display control schematic on page 6-23.

4.6.2.2 The display device U12 is an LSI display controller with digit and segment drivers that execute the μP's LED bit pattern strobed through the multiplex scan circuitry. U55 is a current sourcing driver which is used to buffer the display controllers column driver in the digit scan sequence. U53/U54, with associated resistors, are current-sinking row drivers. The resistors R83 to R90 set the brightness level of the 7-segment and annunciator LED's.

### 4.6.3 Operation.

4.6.3.1 The display controller shares a chip-select signal with the keyboard hardware. The AY2 output from the μP's address decoder U14 is effectively ORed with the μP's clock via pins U7-5/6 and pins U6-8/9/10, the resulting signal is called DSPE. This chip select is supplied as the negative read strobe to the keyboard and the negative write strobe to the display controller.

4.6.3.2 Whenever the μP wishes to update the LED pattern controlled by U12, it latches a string of bytes into U12 from the μP's address bus. The first of these is a status byte which notifies the display controller that 8 data bytes will follow. The display controller differentiates between status bytes and data bytes by sampling the A8 address line during each write cycle (U12-9), which is high during status bytes and low during data byte writes. See Figure 4.18 for a simplified timing diagram.

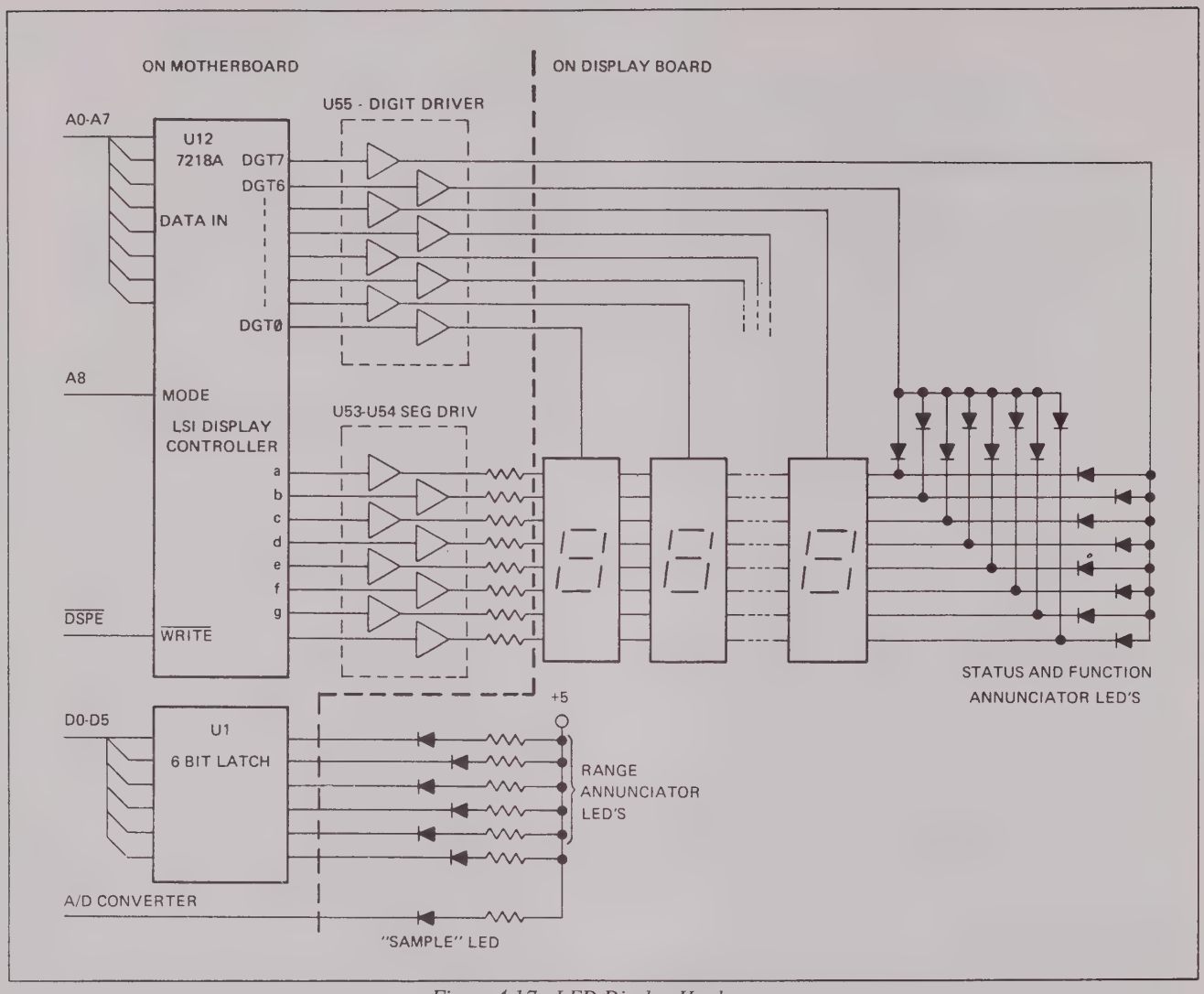



*Figure 4.17 - LED Display Hardware*

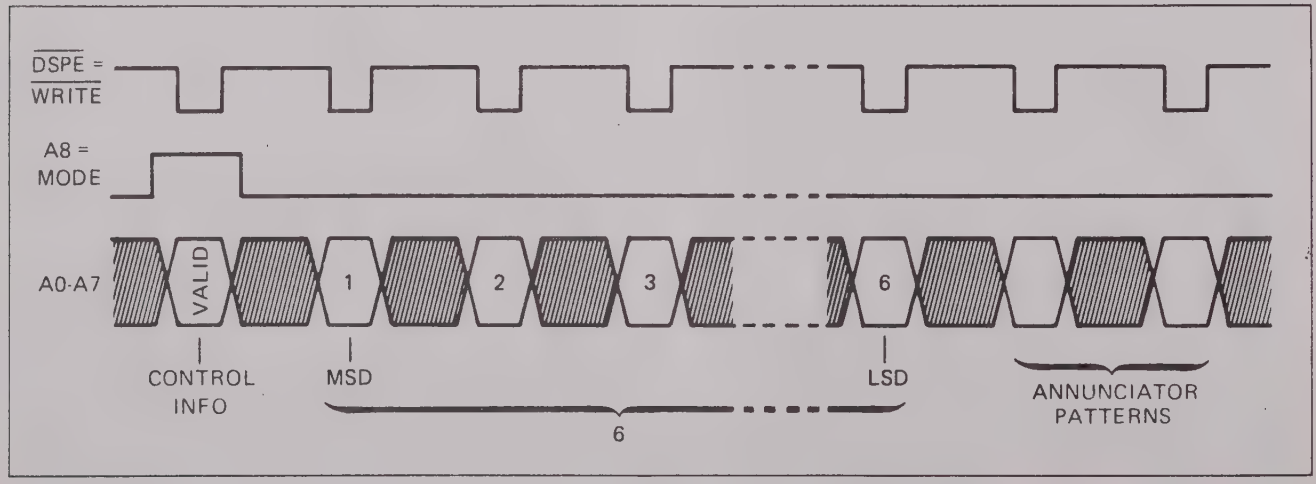



*Figure 4.18 - µP Storage To LSI Display Controller Timing Signals*

4.6.3.3 After all 8 data bytes have been latched into the display controller, it begins to refresh the 7-segment and annunciator LED's. To do this, the display controller first supplies an excitation MUX pattern to its row driver outputs a-g, which are buffered by U53/U54 and appear at the cathodes of all LED's. The display controller then turns on one column driver which, after being buffered by U55, lights the appropriate LED's in that column. After a fraction of a millisecond, the controller turns off the column driver, changes the row excitation pattern, and turns on the next column driver, and so on. The LED refresh rate is fast enough that the human eye cannot detect the flicker.

4.6.3.4 The "Sample" LED located at the lower left corner of the decimal display is not controlled by U12 but instead, receives its control from the analog side of the instrument via OCI-1-10 on page 6-19.

4.6.3.5 The brightness level for the Range LED's is set by the resistor network Z1 on the display PCB.

## 4.7 GPIB INTERFACE: THEORY OF OPERATION.

4.7.1 The DMM's IEEE-488 interface is centered around U44, the 68488 GPIA and positioned in section 8 on the motherboard. The other interface hardware in the GPIB Interface system include U46 and U47 bi-directional buffer/drivers; U37, U38 and U39 the Serial Poll Disable decoder; U45 the GPIA address switch buffer; and U40, U41 and U39 GPIA output holdoff circuit. These devices provide talker/listener capabilities, most interface commands and handle serial poll status bytes. The schematic for the GPIB hardware is listed on page 6-21.

4.7.2 The GPIA interfaces to the GPIB bus via U46 and U47 which are bidirectional octal GPIB transceivers. The U46/U47 data direction signal is controlled by the GPIA transmit/receive (T/R2) signal, from pin U44-27. The GPIA interfaces to the $\mu$P through 14 registers inside the GPIA which are accessed over the $\mu$P's data bus via GPIA pins U44-7 through U44-14.

4.7.3 The microprocessor's address and read/write lines are connected to the GPIA pins 37, 38, 39 and 5 to allow selection of the appropriate internal register by the $\mu$P. If the $\mu$P reads from the GPIA's register 4, the GPIA will not output data to the $\mu$P and will instead drive pin U44-4 low momentarily which will cause U45 to output the address switch setting to the microprocessor.

4.7.4 The GPIA handshakes most in-coming interface messages from the controller and acts upon them without disturbing the $\mu$P. If and when an incoming message or data byte requires a response from the $\mu$P, the GPIA drives its pin U44-40 low which sends an interrupt request IRQ to the $\mu$P via the interrupt control gate U6, which was previously discussed in paragraph 4.5.6. The $\mu$P then examines the GPIA's internal registers to release the IRQ and to determine the cause of the interrupt. The same interrupt sequence takes place if the GPIA is made a talker and has no byte to output.

4.7.5 The GPIB "Output Holdoff Circuit" was added between GPIA pin U44-18 and transceiver pin U47-7 to allow the $\mu$P more complete control to out-going bytes. This holdoff circuit has no effect except when the DMM is a talker, at which time it is used to pace the output of data and serial poll status bytes.

4.7.6 The GPIB Output Holdoff Circuit contains a 2-bit latch U40. The upper half of U40 is used to affect the output of all bytes while the lower half of U40 is dedicated to controlling the output of serial poll status bytes. U41 is a quad analog switch connected to U39 so that U40 is either enabling the passage of signals between pin U44-18 and pin U47-7 or U41 is forcing a zero on pinU44-18to make the GPIA believe that no other 488-bus devices are ready for data.

4.7.7 The ICs U37, U38 and U39 pins 3 to 6 are used to decode the interface message "SPD" (Serial Poll Disable = hex 18) but since data on the bus is inverted, the logic must decode the complement of the SPD message. The output from this logic is OR'd with the single line GPIB message IFC (interface clear), inverted and supplied as the reset input to pin U40-13 so that pin U40-8 will be set back to its normal high state after a serial poll has been completed.

## 5.1 SCOPE.

5.1.1 The maintenance section includes specification checks, calibration procedures, and troubleshooting data required for routine service. Voltage measurements with waveforms tabulated under performance tests are supplied for troubleshooting guidance. A suggested equipment list is covered in Table 5.1. In addition, the program error message list is included with general troubleshooting information. The parts locator shown in Figure 5.4 is a reproduction of the PCB. All component references throughout the Maintenance Section are plainly noted on this drawing.

## 5.2 SPECIFICATION CHECK.

### 5.2.1 Scope.

5.2.1.1 This section contains procedures that compare the operation of the instrument against the published specifications presented at the front of this manual. It is intended to be used for incoming inspection and as a periodic check to determine if the calibration of the instrument meets published specifications. The procedures provide sufficient checks to verify proper operation and that the instrument is within the 6 month accuracy limits. The required ambient temperature of the environment is 23 ± 5 degrees centigrade.

### 5.2.2 Required Equipment.

5.2.2.1 A list of equipment is given in Table 5.1. The specific types of equipment suggested are listed under the Suggested Equipment heading. This list provides a guide for selecting suitable equipment having characteristics equal to or better than the items listed.

### 5.2.3 DC Voltage Sources.

5.2.3.1 To produce voltage levels of necessary accuracy, special techniques are required. Suitable methods of generating these voltages are shown in Figure 5.1 and 5.2, Tables 5.2 and 5.3. A precise and traceable source of 10 volts is required, not only for calibrating the 10 volt range, but

**Table 5.1 - Required Equipment**

| Function | Qty | Item | Minimum Use Specifications | Suggested Equipment |
|---|---|---|---|---|
| DC | (1) | Saturated Standard Cell Bank (6 cells) | 1 ppm, certified | EPPLEY 106 |
| | (2) | DC Voltages Sources | 0.1 ppm resolution | FLUKE 332B |
| | (2) | Voltage Dividers, Adjustable | < 1 ppm linearity | FLUKE 720A |
| | (1) | Decade Resistance Box | | ESI DB62 |
| | (2) | Null Detector/$\mu$Voltmeters | 1 $\mu$V sensitivity | FLUKE 845AR |
| AC | (1) | AC Voltage Source | .05%, 45Hz - 20kHz | FLUKE 5200 A/5215A |
| Ω | (8) | Resistance Standards | Known within: | |
| | | 100Ω | 30 ppm | ESI SR1 with corrections |
| | | 1 KΩ | 30 ppm | ESI SR1 with corrections |
| | | 10 KΩ | 30 ppm | ESI SR1 with corrections |
| | | 100 KΩ | 30 ppm | ESI SR1 with corrections |
| | | 1 MΩ | 30 ppm | ESI SR1 with corrections |
| | | 10 MΩ | 30 ppm | ESI SR1 with corrections |
| OTHER | (1) | Momentary Switch, SPST | – | – |
| | (2) | 1.5 volt cells w/screwtype binding posts | – | – |
| | (1) | Insulated Adjustment tool | – | JFD5284 |
| | (1) | 100Ω, 10 Kilohm, 1 Megohm 1/4 Watt 5% Carbon Resistors | 5% | – |
| | (1) | 1 $\mu$FD non polar capacitor | – | – |

Table 5.2 - DC Source and DMM Accuracies

| Range | 10 Volt Source | Voltage Divider | Total Accuracy | 24 hr. DMM Full Scale Accuracy | Times Better |
|---|---|---|---|---|---|
| 10 | 10 ppm | – | 10 ppm | 100 ppm | 10 |
| 1 | 10 ppm | 1 ppm | 11 ppm | 100 ppm | 9 |
| 100mV | 10 ppm | 1 ppm | 11 ppm | 100 ppm | 9 |
| 100 | 10 ppm | 1 ppm | 11 ppm | 100 ppm | 9 |
| 1000 | 10 ppm | 1 ppm | 11 ppm | 100 ppm | 9 |

also as a reference for generating highly accurate .1, 1, 100, and 1000 volt levels. The 10 volt source used must satisfy the following requirements.

a. It must be traceable to the National Bureau of Standards;

b. It must have a total accuracy of ±10 ppm;

c. It must have a low output impedance.

5.2.3.2 A source filling these requirements is shown in Figure 5.1. This circuit consists of a null detector, 7-decade voltage divider, a DC voltage supply, and a bank of saturated standard cells. Two advantages of this particular hookup are that; (a) there is minimal loading of the standard cells and (b) stability, not accuracy, is the primary requirement of the DC voltage supply. The output of this circuit is set to a precise 10 volts by setting the voltage divider to the value of the standard cells. The DC voltage source is then adjusted to produce a null on the null detector. The accuracy of the 10 volt source is within ±10 ppm. The remainder of the DC sources can be generated by the circuits shown in Table 5.4 and 5.5. Each of these hookups use a calibrated 10 volt source having the characteristics of the one previously described.

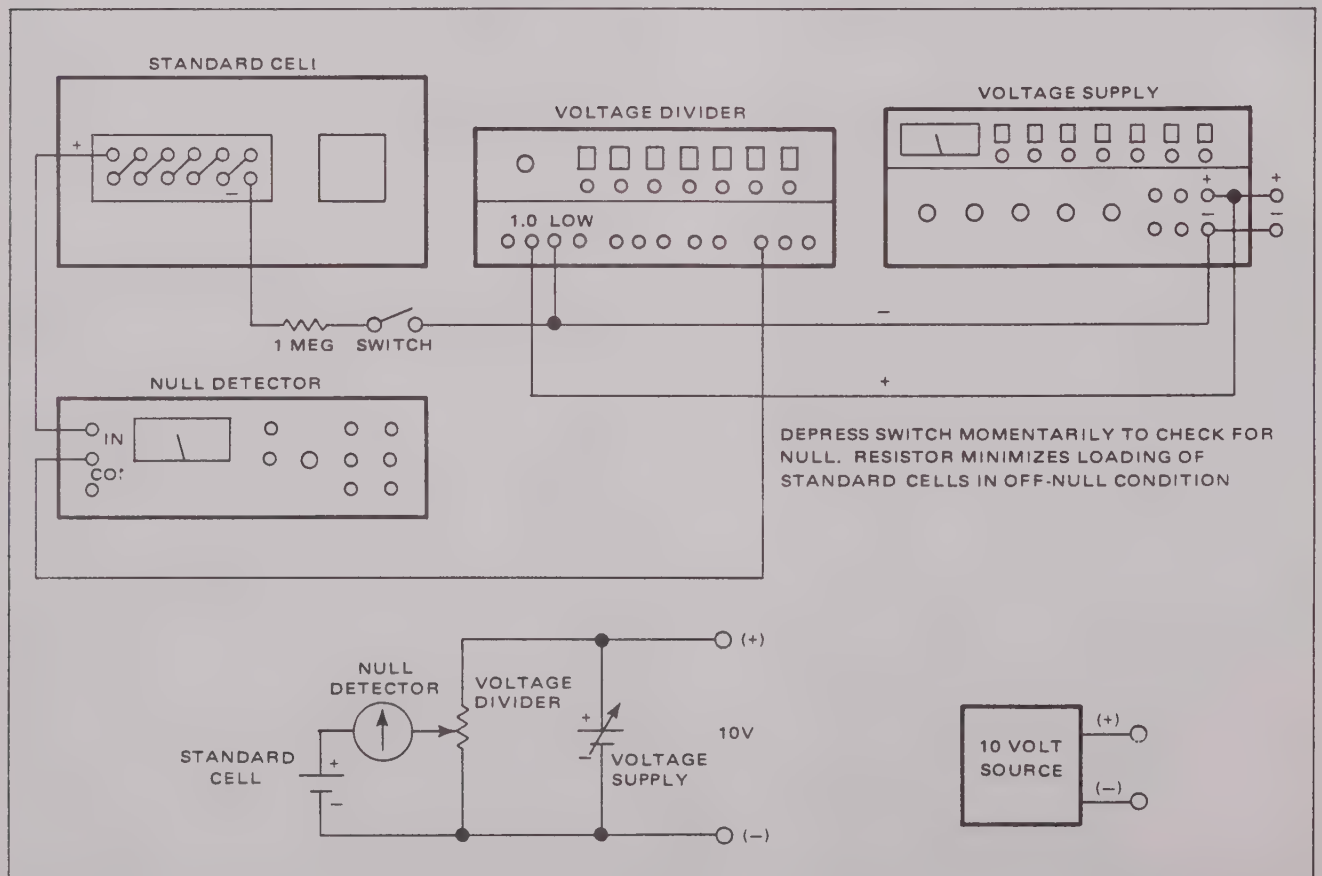





*Figure 5.1 - 10 Volt Source*

### 5.2.4 DC Accuracy.

5.2.4.1 The accuracy of the DC voltage sources is obtained by adding the various sources of error in each hookup; errors in this discussion are defined in parts per million (ppm). In Table 5.2 is shown the errors of each voltage source, the total accuracy of each hookup, the accuracy of the DMM, and the degree to which the sources exceed the required accuracy of the DMM (4 to 10 times better is the suggested accuracy ratio per MIL-M-38793).

### 5.2.5 AC Voltage Source

5.2.5.1 The AC Voltage Source recommended in Table 5.1, or its equivalent, has sufficient accuracy to directly calibrate the 5004 DMM. The calibrator accuracy compared to the 24 hr specifications of the DMM are given in Table 5.3.

**Table 5.3 - AC Source and DMM Accuracies**

| INPUT | | ACCURACIES | | |
|---|---|---|---|---|
| AC Source | | AC Source (Maximum Error) | 24 hr DMM Accuracy | Times Better |
| Volts | Freq | | | |
| 1.0V | 45Hz to 10kHz | +.05% | +0.38% | 8 |
| 10V | | +.05% | +0.38% | 8 |
| 100V | | +.05% | +0.38% | 8 |
| 750V | | +.05% | +0.31% | 6 |
| 1.0V | 10kHz to 20kHz | +.05% | +0.6% | 12 |
| 10V | | +.05% | +0.6% | 12 |
| 100V | | +.05% | +0.6% | 12 |
| 750V | | +.05% | +0.48% | 10 |

### 5.2.6 Test Procedures.

5.2.6.1 Allow two hours for warmup. Connect the instrument and the test equipment as shown in the figure supplied with each accuracy check. Select the controls and inputs as called out in the tables and monitor the instrument readout for the indicated values. Proceed with the tests described in Tables 5.4 through 5.9.

**WARNING**

The following procedures include the use of high voltage sources producing potentially lethal voltages. Avoid contact with high voltage terminals.

## 5.3 CALIBRATION.

5.3.1 This instrument was calibrated to published specifications under closely controlled conditions prior to shipment. The procedures in this section are designed to recalibrate the instrument and keep the instrument operating within specifications.

### 5.3.2 Required Equipment.

5.3.2.1 A list of equipment required for calibration is given in Table 5.1. The specific equipment types are given only as a guide. If substitutions are made, the substituted equipment must meet or exceed the specifications of the equipment listed.

### 5.3.3 DC & AC Voltage Sources.

5.3.3.1 See Sections 5.2.3, 5.2.4, and 5.2.5.

### 5.3.4 Calibration Principles.

5.3.4.1 Calibration procedure for the DMM utilizes microprocessor controlled adjustments. The calibration adjustments executed through the keyboard input or GPIB commands are the software method of setting correction factors.

5.3.4.2 The Non-Volatile Constants memory of the DMM enables the microprocessor to perform software calibrations. Inputs are applied to the DMM from the calibration standard and the reading is incremented or decremented via keyboard control or GPIB commands until the reading equals the input standard. During this process, the numeric constants for analog offset voltages and scale factor corrections are loaded into the Non-Volatile memory by the microprocessor ($\mu$P). These constants are then used by the $\mu$P to correct each DMM reading before display or readout to the GPIB.

5.3.4.3 In order to enter correction constants into the Non-Volatile memory, three conditions are required:

a. The correct input standard for the function and range selected is applied to the DMM.

b. The calibration switch (Cal-Sw) must remain depressed during the adjustment process.

c. A keyboard input or GPIB command is required to increment or decrement the reading to equal the input standard.

IMPORTANT REMINDER

KEYBOARD OR GPIB CALIBRATION COMMANDS ARE "NOT" EFFECTIVE UNLESS THE CAL-SW IS HELD IN THE DEPRESSED POSITION. NUMBERS ARE ENTERED INTO THE NON-VOLATILE MEMORY ONLY WHEN THE CAL-SW IS IN THE "DEPRESSED POSITION".

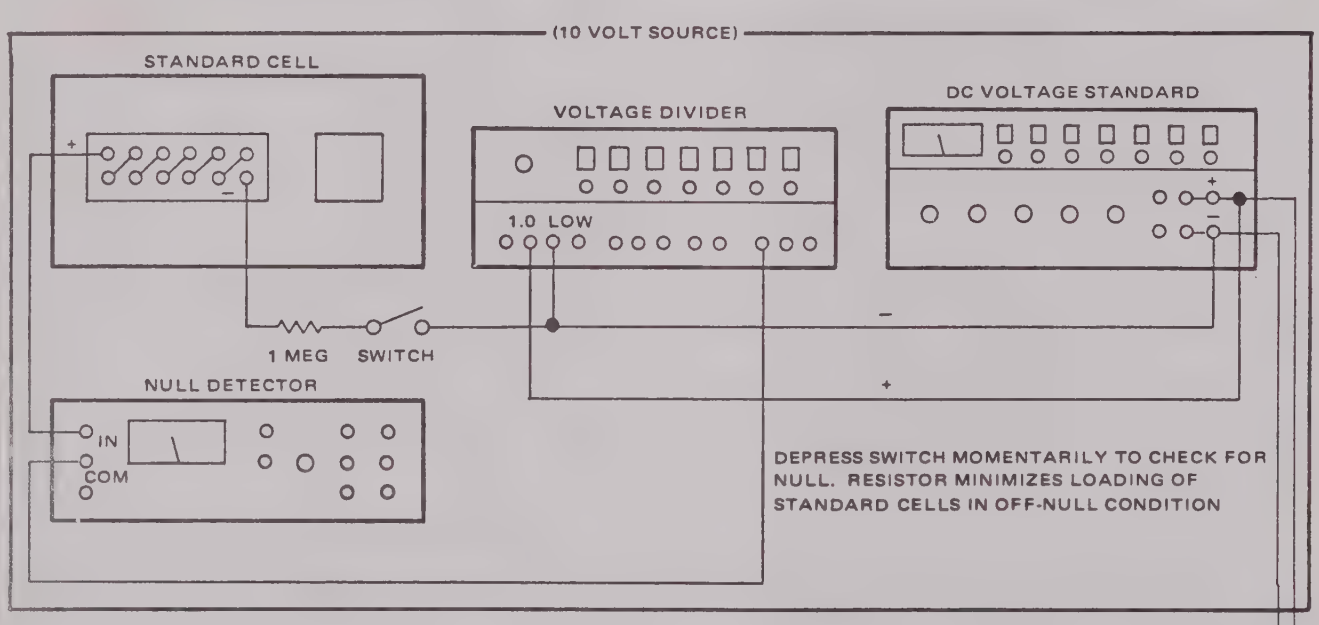
5.3.4.4 The Cal-Sw is a momentary contact switch accessible through an opening on the front panel (see Figure 3.1 No. 8 for location). The switch can be depressed by inserting

an appropriate size screwdriver or similar tool through the opening.

5.3.4.5 The DMM Function, Range and Input Standard for each entry into the Non-Volatile memory is listed in Table 5.10. One offset correction factor is entered for each Function and a scale factor is entered for each Range. In the DC Function, scale factors are entered for both positive and negative inputs, additionally a scale factor correction constant is entered for the 4 1/2 digit mode.

**Table 5.4 - DC Function Check (Low Ranges)**

| DVM | | INPUT SIGNAL | | NOMINAL READING | TOLERANCE (6 MO. SPEC.) 5-1/2 DIGIT MODE | NOTE |
|---|---|---|---|---|---|---|
| FUNCTION | RANGE | DC VOLTAGE STANDARD | VOLTAGE DIVIDER SETTING | | | |
| DC | .1V | 10.00000 | .01000 | .100000 | .099974 – .100026 | 23°C ± 5°C (After DIGITAL ZERO Command) |
| | | 10.00000 | .02000 | .200000 | .199954 – .200046 | |
| | 1V | 10.00000 | .10000 | 1.00000 | .99984 – 1.00016 | |
| | | 10.00000 | .20000 | 2.00000 | 1.99974 – 2.00026 | |



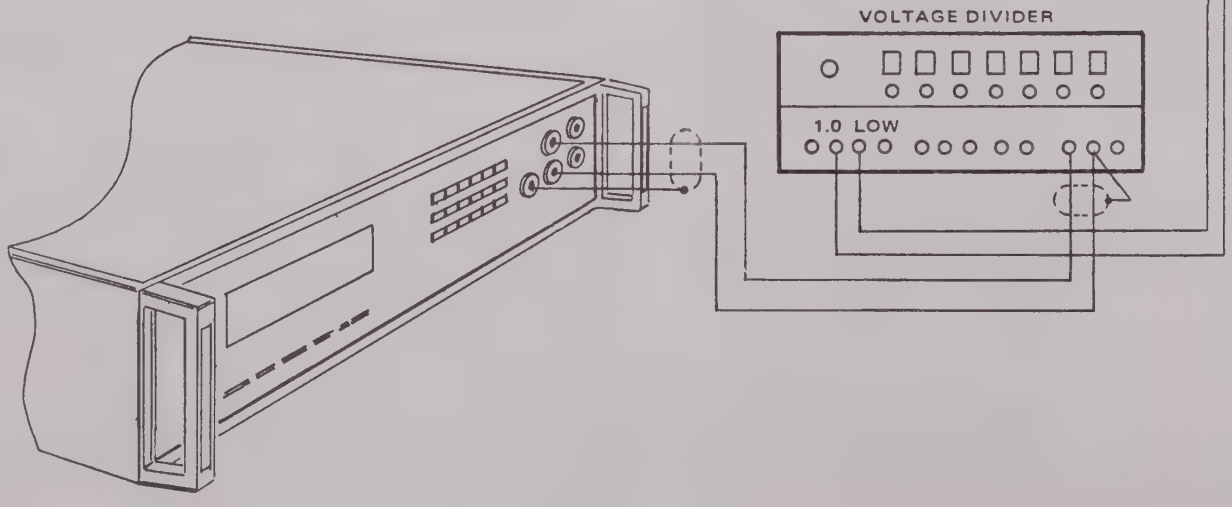



Table 5.5 - DC Function Check (High Ranges)

| DVM | | INPUT SIGNAL | | NOMINAL READING | TOLERANCE (6 MO. SPEC.) 5-1/2 DIGIT MODE | NOTE |
|---|---|---|---|---|---|---|
| FUNCTION | RANGE | DC VOLTAGE STANDARD | VOLTAGE DIVIDER SETTING | | | |
| DC | 10 | 10.0000V | 1.0000 | 10.0000 | 9.9974 – 10.0026 | 23°C ± 5°C (After DIGITAL ZERO Command) |
| | | 20.0000V | .50000 | 20.0000 | 19.9954 – 20.0046 | |
| | 100 | 100.000V | .10000 | 100.000 | 99.974 – 100.026 | |
| | | 200.000V | .05000 | 200.000 | 199.954 – 200.046 | |
| | 1000 | 1000.00V | .01000 | 1000.00 | 999.74 – 1000.26 | |

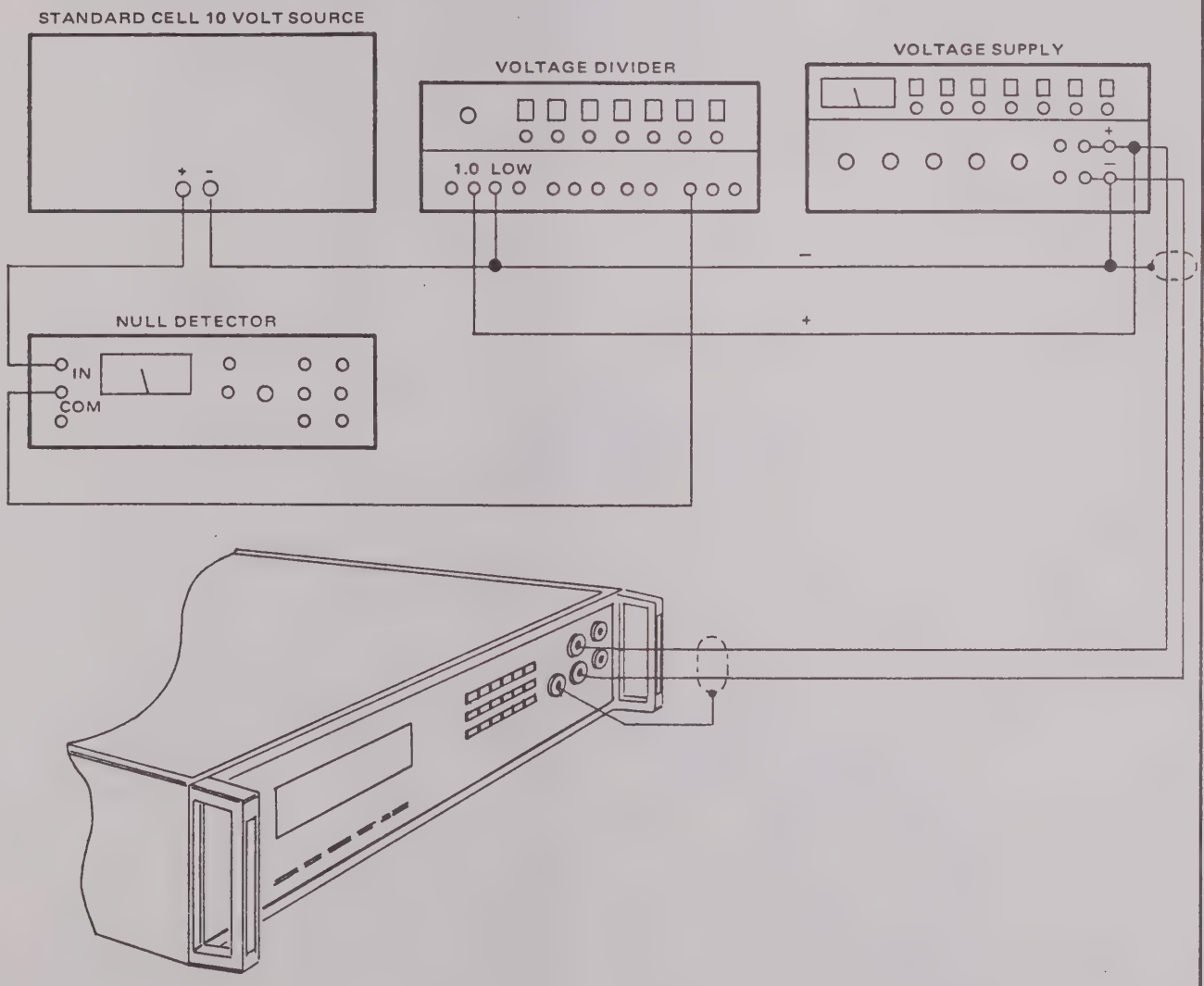


Table 5.6 - RMS AC Function

| DVM | | INPUT SIGNAL | | NOMINAL READING | TOLERANCE (6 MO. SPEC.) 5-1/2 DIGIT MODE | NOTE |
|---|---|---|---|---|---|---|
| FUNCTION | RANGE | | AC RMS VALUE | | | |
| AC | 1 | | 1V @ 400 Hz | 1.00000 | .99400 – 1.00600 | 23°C ± 5°C |
| | | | 1V @ 20 KHz | 1.00000 | .99100 – 1.00900 | |
| | 10 | | 10V @ 400 Hz | 10.0000 | 9.9400 – 10.0600 | |
| | | | 10V @ 20 KHz | 10.0000 | 9.9100 – 10.0900 | |
| | 100 | | 100V @ 400 Hz | 100.000 | 99.400 – 100.600 | |
| | | | 100V @ 20 KHz | 100.000 | 99.100 – 100.900 | |
| | 1K | | 750 V @ 400 Hz | 750.00 | 745.25 – 754.75 | |
| | | | 750 V @ 20 KHz | 750.00 | 742.88 – 757.12 | |
| | | | | | | |

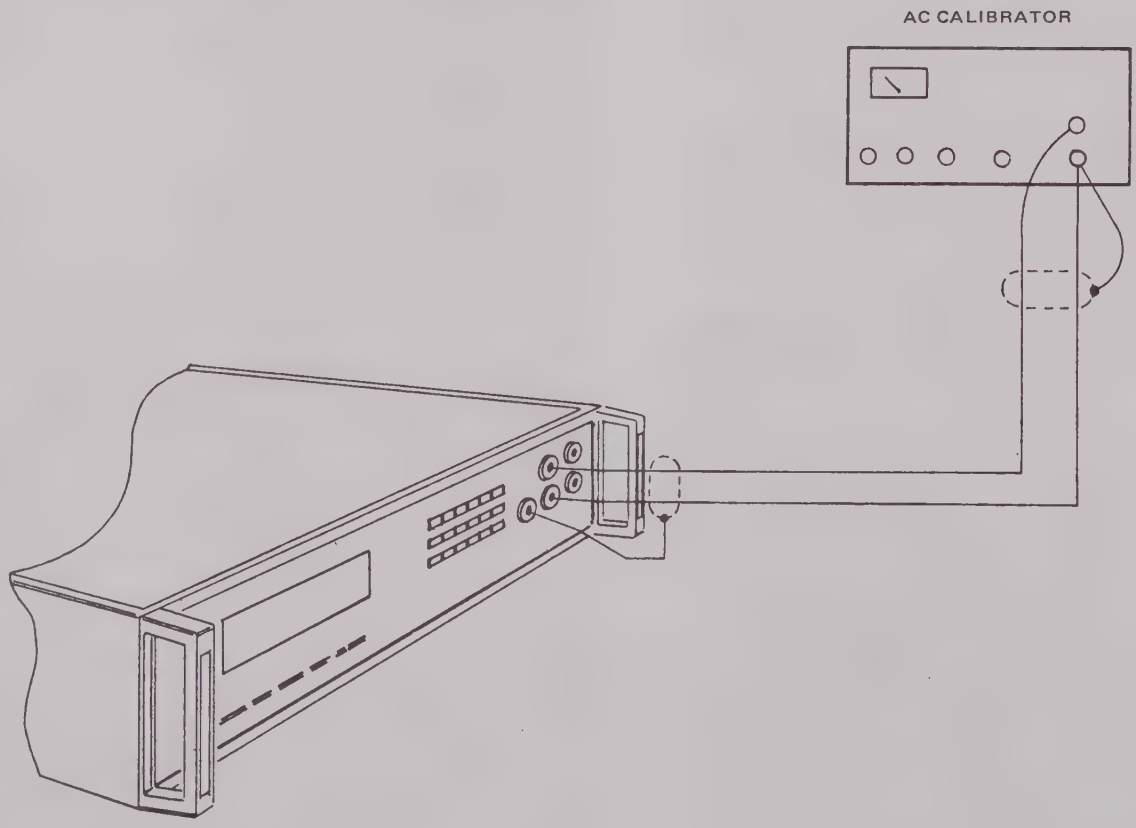


Table 5.7 - K Ohms Function

| DVM | | INPUT SIGNAL | | TOLERANCE* (6 MO. SPEC.) 5-1/2 DIGIT MODE | NOTE |
|---|---|---|---|---|---|
| FUNCTION | RANGE | NOMINAL STANDARD VALUE | | | |
| KΩ | .1KΩ | 100Ω | | ± 110 digits | 23°C ± 5°C |
| | 1 KΩ | 1 KΩ | | ± 110 digits | |
| | 10 KΩ | 10 KΩ | | ± 110 digits | |
| | 100 KΩ | 100 KΩ | | ± 110 digits | |
| | 1000 KΩ | 1 MΩ | | ± 110 digits | |
| | 10000 KΩ | 10 MΩ | | ± 110 digits | |

*After DIGITAL ZERO Command.

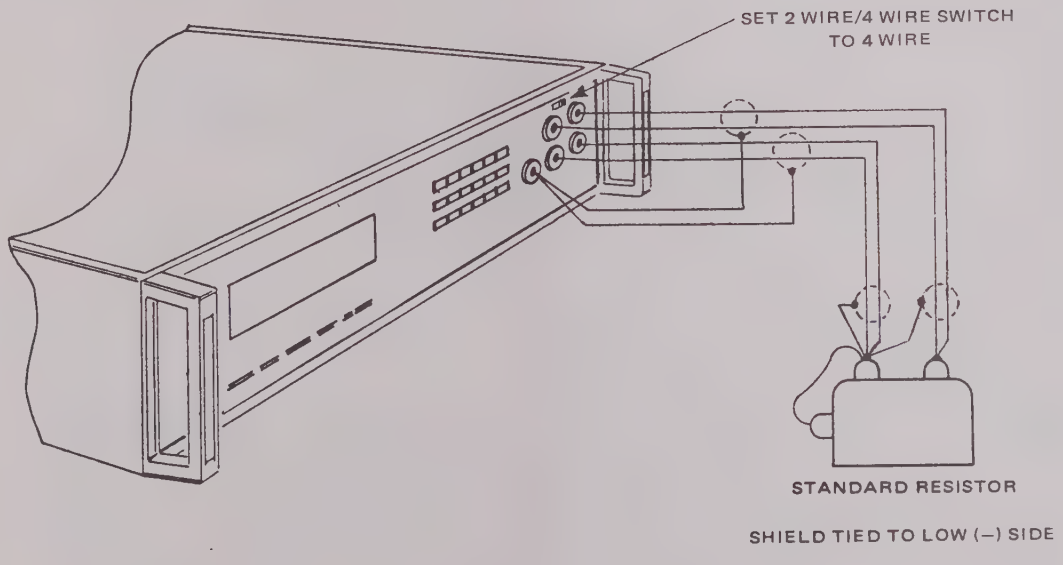


Table 5.8 - Normal Mode Noise Rejection (In DC Volts Function)

| DVM | | INPUT SIGNAL | | NOMINAL READING | TOLERANCE | NOTE |
|---|---|---|---|---|---|---|
| FUNCTION | RANGE | DC | AC | | | |
| DC | 10 | 0.5V | 7.07V RMS 60 Hz* | 00.5000 | ± 100 digits | |

*50 Hz for 50 Hz Instruments.

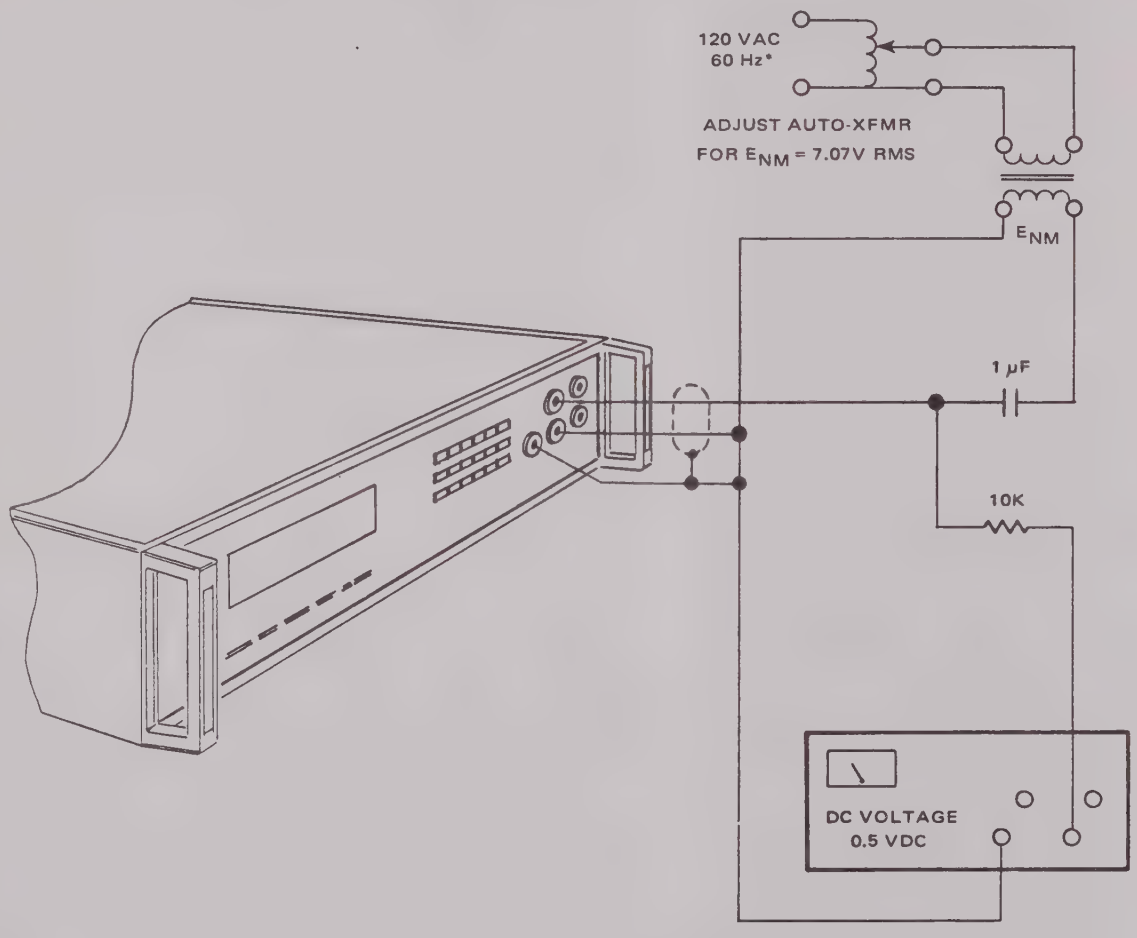
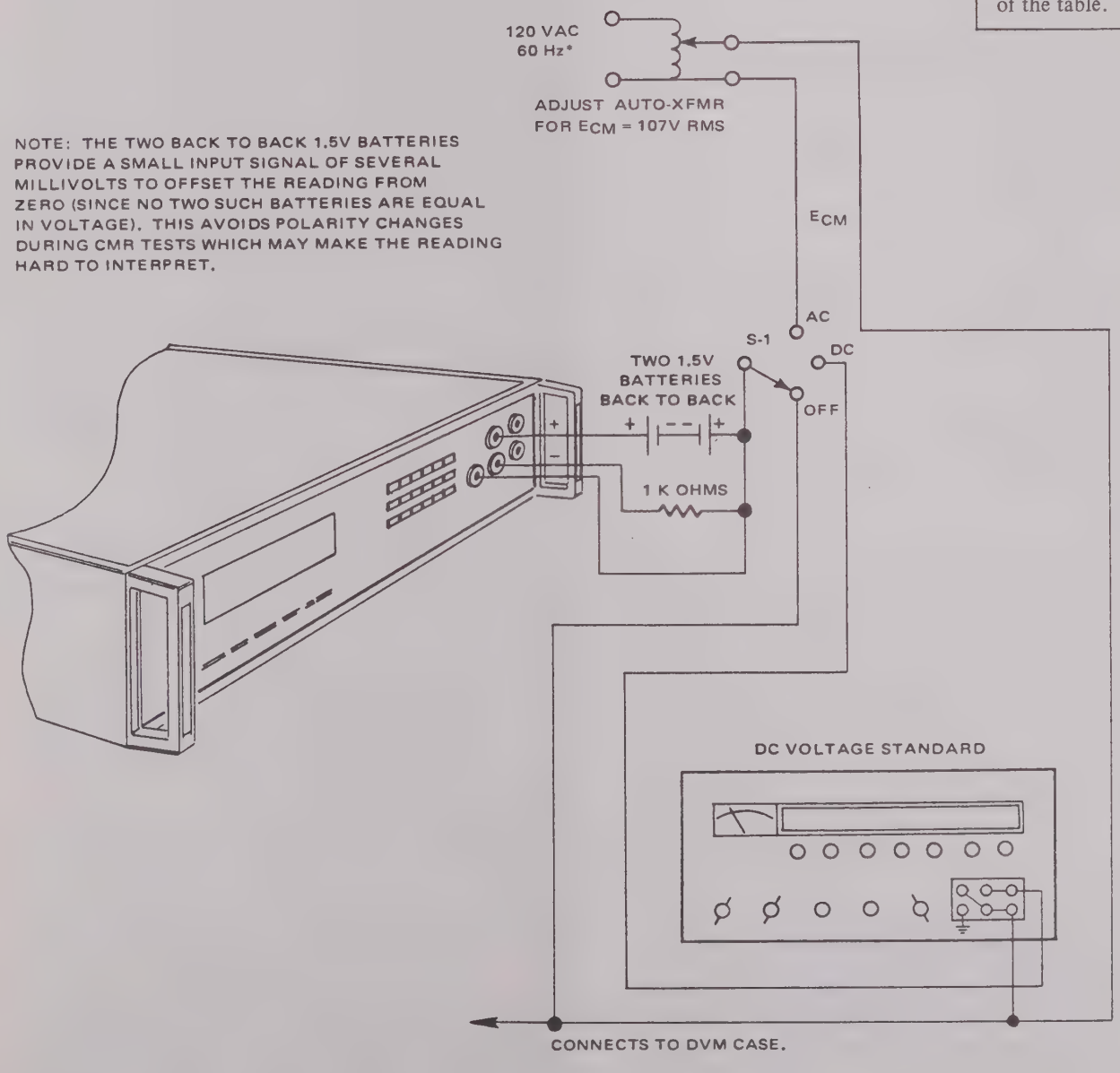


**Table 5.9 - Common Mode Rejection (In DC Volts Function)**

| DVM | | INPUT SIGNAL | | NOMINAL READING See Note 1 | TOLERANCE | NOTE |
|---|---|---|---|---|---|---|
| FUNCTION | RANGE | S1 | | | | |
| DCV | 1V | Off | | | | 1) With switch S-1 in the off position, record the reading displayed on the DMM's readout in the "nominal reading" boxes of the table. |
| | | DC | 1000V | | ± 10 digits from nominal | |
| | | AC | 107V RMS 60 Hz* | | 30 digits peak-to-peak | |

*50 Hz for 50 Hz Instruments.


120 VAC
60 Hz*
ADJUST AUTO-XFMR
FOR ECM = 107V RMS
NOTE: THE TWO BACK TO BACK 1.5V BATTERIES PROVIDE A SMALL INPUT SIGNAL OF SEVERAL MILLIVOLTS TO OFFSET THE READING FROM ZERO (SINCE NO TWO SUCH BATTERIES ARE EQUAL IN VOLTAGE). THIS AVOIDS POLARITY CHANGES DURING CMR TESTS WHICH MAY MAKE THE READING HARD TO INTERPRET.
ECM
AC
S-1
DC
OFF
TWO 1.5V BATTERIES BACK TO BACK
1 K OHMS
DC VOLTAGE STANDARD
CONNECTS TO DVM CASE.

5.3.4.6 MANUAL CALIBRATION

5.3.4.6.1 The DMM procedure to enter corrections using the keyboard command is as follows:

a. Offset Correction Factors: Zero volts or ohms are applied to the DMM.

b. Scale Factor Corrections: A full scale input is applied in each Function and Range.

c. Three input keys on the keyboard which perform the UP count, DOWN count, and NOMINAL functions are described below.

1. UP Key: Performed by depressing the RECALL key and referred to as RECALL/UP. This key increments the numbers in memory while the Cal-SW is held depressed.

2. DOWN Key: Performed by depressing the STORE key and referred to as STORE/DOWN. This key decrements the numbers in memory while the Cal-SW is held depressed.

3. NOMINAL Key: Performed by depressing the RESET key and referred to as RESET/NOMINAL. This key initializes the numbers in memory while the Cal-SW is held depressed, as explained in the next paragraph.

**Table 5.10 - Non-Volatile Memory Constants**

| Memory Constant | Calibration Conditions | | |
|---|---|---|---|
| | Function | Range | Input |
| DC Offset | DC | .1V | Zero |
| .1V Pos. Scale Factor | DC | .1V | +.1VDC |
| .1V Neg. Scale Factor | DC | .1V | −.1VDC |
| 1V Pos. Scale Factor | DC | 1V | +1VDC |
| 1V Neg. Scale Factor | DC | 1V | −1VDC |
| 10V Pos. Scale Factor | DC | 10V | +10VDC |
| 10V Neg. Scale Factor | DC | 10V | −10VDC |
| 100V Pos. Scale Factor | DC | 100V | +100VDC |
| 100V Neg. Scale Factor | DC | 100V | −100VDC |
| 1KV Pos. Scale Factor | DC | 1KV | +1KVDC |
| 1KV Neg. Scale Factor | DC | 1KV | −1KVDC |
| 4 1/2 Digit Scale Factor | DC | 1V | ±2VDC |
| AC Offset | AC | 1V | .01V RMS, 1 KHz |
| 1V Scale Factor | AC | 1V | 1V RMS, 1 KHz |
| 10V Scale Factor | AC | 10V | 10V RMS, 1 KHz |
| 100V Scale Factor | AC | 100V | 100V RMS, 1 KHz |
| 1KV Scale Factor | AC | 1KV | 750V RMS, 1 KHz |
| Ohms Offset | KΩ | 100K | Zero |
| .1KΩ Scale Factor | KΩ | .1K | 100Ω |
| 1KΩ Scale Factor | KΩ | 1K | 1KΩ |
| 10KΩ Scale Factor | KΩ | 10K | 10KΩ |
| 100KΩ Scale Factor | KΩ | 100K | 100KΩ |
| 1000KΩ Scale Factor | KΩ | 1000K | 1MΩ |
| 10,000KΩ Scale Factor | KΩ | 10,000K | 10MΩ |

5.3.4.6.2 The RESET/NOMINAL key is used to initialize the numbers in Non-Volatile memory. When this key is depressed and released, either a ZERO is entered into the Non-Volatile memory as an offset correction factor, provided the DMM input is less than 40% of full scale, or a ONE is entered into the Non-Volatile memory as a scale factor, provided the DMM input is greater than 40% of full scale.

5.3.4.6.3 The STORE/DOWN key decrements the numbers in the Non-Volatile memory. This action is described as follows:

a. When entering an offset correction factor, this key changes the reading in a "Negative going" direction. For example, if the DMM reading is .00023 for zero input in the DC function, each time the STORE/DOWN key is depressed and released, the reading will decrease one digit. Upon reaching .00000, calibration of the DC offset correction factors is complete. Further depression of this key will cause the reading to increase with a negative polarity indication.

b. When entering scale factors, each depression of the STORE/DOWN key will decrease the displayed reading one digit when a Full Scale Input is applied.

c. When the decrements required for corrections are numerous, holding the STORE/DOWN key depressed longer than two seconds approximately, will decrement the readings as a faster rate as long as the key remains depressed.

5.3.4.6.4 The RECALL/UP key increments the numbers in the Non-Volatile memory. This action is described as follows:

a. When entering an offset correction factor, this key changes the reading in a "Positive going" direction. For example, if the DMM reading is −.00023 for zero input in the DC Function, each time the RECALL/UP key is depressed and released, the reading will decrease one digit. Upon reaching .00000, calibration of the DC offset correction factor is complete. Further depression of this key will cause the reading to increase with a positive polarity indication.

b. When entering scale factors, each depression of the RECALL/UP key will increase the display reading one digit as a Full Scale input is applied.

c. When the increments required for corrections are numerous, holding the RECALL/UP key depressed longer than two seconds approximately, will increment the readings at a faster rate as long as the key remains depressed.

5.3.4.6.5 In situations where the input standard and the initial reading differ by several hundred digits, the difference can be reduced at the fastest rate by switching to the 4 1/2 digit mode (depress and release RESOL key). In the 4 1/2 digit mode, each depression of the RECALL/UP or STORE/DOWN key changes the reading one digit, which is 10 digits on the 5 1/2 digit mode. Holding either key depressed for fast increment or decrement operation also changes the reading in 10 digit increments. Once the reading has been reduced to within a few digits of the input standard in the 4 1/2 digit mode, switch back into the 5 1/2 digit operation to complete the calibration.

5.3.4.6.6 When using the 4 1/2 digit mode to change the reading rapidly, the DMM "must be in a fixed range" (AUTO ranging disabled and AUTO annunciator OFF). When this precaution is not taken, the 4 1/2 digit Scale Factor will be modified instead of the desired Non-Volatile memory constant.

5.3.4.6.7 If the 4 1/2 digit Scale Factor is inadvertently modified, the 4 1/2 and 5 1/2 digit readings will differ. To re-initialize the 4 1/2 digit Scale Factor, the following procedure is presented.

a. Select the DC Function any Range, 4 1/2 digit mode, Auto-ranging (Auto-annunciator ON).

b. Apply a full scale input to the DMM for the Range selected in (a.).

c. Depress and hold the calibration switch.

d. Depress and release the RESET/NOMINAL key.

e. Release the calibration switch.

**WARNING**

These instructions are for use by qualified personnel only. To avoid electric shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

5.3.4.7 GPIB CALIBRATION

5.3.4.7.1 When calibration is performed via the GPIB, it is convenient to short the Cal-Sw terminals with a temporary jumper. The Cal-Sw drawing shown in Figure 5.2 indicates the location of the jumper.

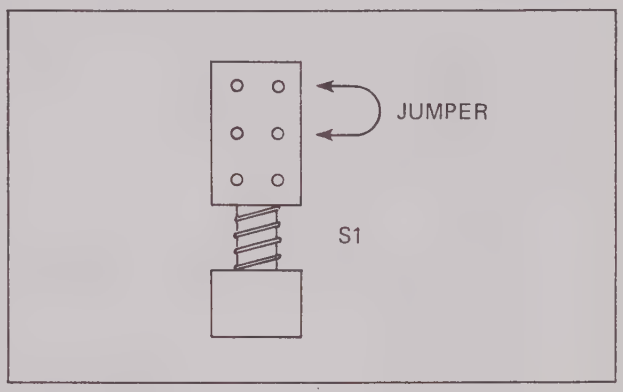



*Figure 5.2 Cal-Switch, Top View*

**IMPORTANT**

Connect the jumper after power is applied to the DMM and disconnect the jumper before power is removed. If this instruction is not followed, the contents of the Non-Volatile memory will be destroyed and "Error 4" will be displayed the next time power is applied to the DMM.

5.3.4.7.2. GPIB commands K3 through K5 affect the Offset constant for the Function which is presently programmed. Each transmission of the K3 or K5 command to the DMM is equivalent to applying a low-level input (Low level is less than 40% and high-level is greater than 40% of Full Scale.), and momentarily pressing the STORE/DOWN or RECALL/UP keys on the DMM front panel. Transmitting the K4 command is equivalent to the keyboard procedure for initializing offset constants, with the exception that the input signal need not be less than 40% of full scale when initializing offset constants over the bus.

5.3.4.7.3 GPIB commands K6 through K8 affect the Scale constants for the range which is presently programmed. Each transmission of the K6 or K8 command to the DMM is equivalent to applying a high level input and momentarily pressing the STORE/DOWN or RECALL/UP keys on the DMM front panel.

5.3.4.7.4 Transmitting the K7 command has the same effect as initializing scale constants from the keyboard. To initialize a scale factor over the GPIB, the following procedure is provided:

a. Apply a high-level input signal.

b. Complete at least one reading on the presently programmed function/range.

c. Transmit the K7 command to the DMM.

**NOTE**

a. The K4 and K7 commands should not be required unless the contents of the non-volatile are destroyed.

b. Check with your Racal-Dana Representative to obtain a copy of the soon to be released GPIB application notes which details a complete GPIB calibration procedure.

### 5.3.5 Calibration Procedure.

NOTE: Some adjustment and calibration procedures will not function properly if the nonvolatile memory does not contain "reasonable" cal factors. Therefore, if nonvolatile memory is suspected of containing erroneous data, it should first be initialized using the procedure in Section 5.3.6.

NOTE: If repairs have been completed recently, see Section 5.3.6 first.

5.3.5.1 OHMS AMPLIFIER OFFSET ZERO (R1).

a. Short the INPUT terminals and GUARD terminal together.

b. Select DC Function, .1V Range.

c. Allow instrument at least one hour warm up with covers in place.

d. Hold the .1 Range key depressed, until "CAL 0" appears on the display, then release the key.

**WARNING**

These instructions are for use by qualified personnel only. To avoid electric shock, do not perform any servicing other than that contained in the operating instructions unless you are qualified to do so.

e. Remove top cover.

f. Select OHMS Function, 100KΩ Range.

g. Adjust R1 until the display reads less than ± 5 digits. See Figure 5.4 for R1 location.

5.3.5.2 INPUT BIAS CURRENT NULL (R53).

a. Connect the Decade Resistance Box across the INPUT terminals. Select DC Function, .1V Range and FILTER.

b. Allow instrument at least one hour warmup with covers in place.

c. Switch Decade Resistance Box between 0 and 1 Megohm. If display changes more than 50 digits as Decade box is switched, proceed to steps (d.) and (e.).

**WARNING**

Removal of covers exposes potentially lethal voltages. Avoid contact with internal electrical connections while unit is connected to AC Power source.

d. Remove top cover for access to R53, but keep cover in place when not adjusting R53.

e. Adjust R53 until display changes less than 50 digits as Decade box is switched between 0 and 1 megohm. See Figure 5.4 for R53 location.

5.3.5.3 "DIGITAL" CALIBRATION.

a. Verify that all shields and covers are installed.

b. Short the INPUT terminals and GUARD terminal together.

c. Allow at least 2 hours warmup with covers installed before proceeding.

**Table 5.11 - Calibration Points for Entry of Final Values Into Non-Volatile Memory**

| Function | Range | Input Standard | Input Connections | Notes |
|---|---|---|---|---|
| DC | .1V | 0.00000 VDC | Table 5.4 | Note 1 - See paragraph 5.3.5.5 to calibrate 4 1/2 Digit mode.<br>Note 2 - These two steps interact. Repeat as necessary.<br>Note 3 - The value of the Resistance Standard must be known to within the tolerance indicated in Table 5.1. |
| | .1V | +0.1 VDC | | |
| | .1V | −0.1 VDC | | |
| | 1V | +1.0 VDC | | |
| | 1V | −1.0 VDC | | |
| | 1V | (Note 1) | | |
| | 10V | +10.0 VDC | Table 5.5 | |
| | 10V | −10.0 VDC | | |
| | 100V | +100.0 VDC | | |
| | 100V | −100.0 VDC | | |
| | 1KV | +1000.0 VDC | | |
| | 1KV | −1000.0 VDC | | |
| AC | 1V | .01V RMS, 1 KHz | Table 5.6 } Note 2 | |
| | 1V | 1.0V RMS, 1 KHz | | |
| | 10V | 10.0V RMS, 1 KHz | | |
| | 100V | 100.0V RMS, 1 KHz | | |
| | 1KV | 750 .0V RMS, 1 KHz | | |
| KΩ | 100KΩ | 0.0Ω | Table 5.7 | |
| | .1KΩ | 100.0Ω } Note 3 | | |
| | 1KΩ | 1.0KΩ | | |
| | 10KΩ | 10.0KΩ | | |
| | 100KΩ | 100.0KΩ | | |
| | 1000KΩ | 1.0MΩ | | |
| | 10,000KΩ | 10.0MΩ | | |

d. Select DC Function. Hold the .1V Range key depressed until "CAL 0" appears on the display, then release the Key.

e. Depress and hold the Calibration Switch.

f. Depress and release the RESET/NOMINAL Key.

g. Disable the Auto-range function by depressing the .1V Range Key. The AUTO annunciator will be OFF when disabled.

h. Refer to Table 5.11 for the Function, Range and Input for each calibration point. Verify that the AUTO annunciator remains OFF at each calibration point unless otherwise instructed.

5.3.5.4 5 1/2 DIGIT MODE CALIBRATION.

a. Connect the DMM to the Input Standard as specified for the first calibration point in Table 5.11. Apply 0.00000 VDC to the DMM by dialing the Voltage Divider to zero.

b. Depress and hold the Calibration Switch.

c. If the reading is not zero (4 digits p-p noise allowed), proceed to step (d); if equal to zero, release the Calibration Switch and proceed to step (f).

d. Increment or decrement the reading with the STORE/DOWN or RECALL/UP keys or GPIB command until the reading is zero.

e. Release the Calibration Switch.

f. Connect the DMM to the Input Standard as specified for the next calibration point in Table 5.11.

g. If the DMM reading is not equal to the Input Standard, proceed to step (h); if equal to the Standard, release the Calibration Switch and proceed to step (k.).

h. Depress and hold the Calibration Switch.

i. Increment or decrement the reading with the STORE/DOWN or RECALL/UP keys (or GPIB Command) until the reading is equal to the Input Standard.

j. Release the Calibration Switch.

k. Repeat steps (f.) thru (j.) for each calibration point in Table 5.11, except the 4 1/2 Digit Mode Scale Factor. At that step, see 5.3.5.5. Calibration is completed.

5.3.5.5 4 1/2 DIGIT MODE SCALE FACTOR CALIBRATION.

a. Switch to the 4 1/2 Digit Mode (depress RESOL Key) and Auto-ranging (depress AUTO Key - verify that AUTO annunciator is ON).

b. Apply +2.0000 VDC and note reading.

c. Apply −2.0000 VDC and note reading.

d. Depress and hold the Calibration Switch.

e. If the opposite polarity readings in (b) and (c) above are equal in magnitude, but not equal to 2.0000, increment or decrement either polarity reading with the STORE/DOWN or RECALL/UP Keys (or GPIB Command) until the readings are 2.0000 + 1 digit.

f. If the opposite polarity readings are not equal in magnitude, increment or decrement either polarity reading until the readings are within ±3 digits of 2.0000.

g. Release Calibration Switch.

### 5.3.6 Adjustments After Repairs.

5.3.6.1 If major repairs are performed on the Isolator or Ohms Amplifier, offset and bias adjustments associated with these circuits may need adjustment. Also, if repair work is performed in the vicinity of the non-volatile memory, or battery power is interrupted, the contents of the non-volatile memory may be invalidated. This is indicated by the presence of the message "Error 4" shortly after power-up.

5.3.6.2 ISOLATOR ADJUSTMENT.

a. Input Bias Current Null (R53) - See paragraph 5.3.5.2.

5.3.6.3 OHMS AMPLIFIER ADJUSTMENT.

a. Offset Zero (R1) - See paragraph 5.3.5.1.

5.3.6.4 INITIALIZING NON-VOLATILE MEMORY.

a. Refer to Table 5.12 for the Function, Range and Input for each Non-Volatile memory calibration point.

**Table 5.12 - Inputs for Initializing Non-Volatile Memory**

| Function | Range | Input Standard (Note 1) |
|---|---|---|
| DC | .1V | 0.0 VDC |
| | .1V | +0.1 VDC |
| | .1V | +0.1 VDC (Note 2) |
| | .1V | −0.1 VDC |
| | 1V | +1.0 VDC |
| | 1V | −1.0 VDC |
| | 10V | +10 VDC |
| | 10V | −10 VDC |
| | 100V | +100 VDC |
| | 100V | −100 VDC |
| | 1KV | +1000 VDC |
| | 1KV | −1000 VDC |
| AC | 1V | 0 to .1V RMS, 1 KHz |
| | 1V | 1V RMS, 1 KHz |
| | 10V | 10V RMS, 1 KHz |
| | 100V | 100V RMS, 1 KHz |
| | 1KV | 750V RMS, 1 KHz |
| KΩ | 100KΩ | 0.0Ω (Note 3) |
| | .1KΩ | 100Ω |
| | 1KΩ | 1KΩ |
| | 10KΩ | 10KΩ |
| | 100KΩ | 100KΩ |
| | 1000KΩ | 1MΩ |
| | 10,000KΩ | 10MΩ |

Note 1 - Unless otherwise noted, ± 10% accuracy is adequate.
Note 2 - Select 4 1/2 Digit mode (RESOL Key) and auto-ranging (AUTO Key) for this calibration only. Return to 5 1/2 Digit mode (RESOL Key), fixed range before continuing to the next step.
Note 3 - Either 2-wire or 4-wire connections are satisfactory.

b. At each point in the Table, set the DMM to the indicated Function and Range, and apply the specified input.

c. Depress and hold the Calibration switch.

d. While the Calibration Switch is held depressed, press and release the RESET/NOMINAL Key.

e. Release the Calibration Switch.

## 5.4 TROUBLESHOOTING.

### 5.4.1 General.

5.4.1.1 To troubleshoot the DMM and track-down malfunctions it is necessary to be familar with its normal operation. This manual is an important service tool, hence reading the complete manual is recommended.

**Table 5.13 - Test Equipment**

| Item | Minimum Use Specification | Calibration Equipment |
|---|---|---|
| DC Power Supply | Adjustable 0-20 VDC | – |
| Oscilloscope | 25 MHz Bandwidth | TEK 454 |
| DMM | 0.1% DCV | Racal-Dana 6000 |

5.4.1.2 A complete set of schematics for the DMM is contained in Section 6, which includes the parts list and parts lay-out. The components, IC's and logic symbols used in the schematic diagrams are identical to those found in most manufacturers data sheets. Whenever a designator appears which is unique to Racal-Dana, the description follows immediately.

5.4.1.3 The drawing interconnects and continuations to other sheets are indicated in the following manner:

a. Plugs and Jacks: "P" indicates the plug or male section of the connector and J the jack or receptacle. P or J with the numbers from 1 to 99 are used on the main PCB or motherboard locations, whereas P or J 100 series are on the front panel location and P or J 200 series represents the rear panel location. The E terminals are used for direct connection to the main PC board.

b. The drawing or schematic continuation from one sheet to the next utilize the road-map grid system, with numbers along the horizontal edge and letters along the vertical edge of the drawing. A line terminating with a continuation reference of 2B4 would read: sheet two, row B and column 4.

### 5.4.2 Software Troubleshooting.

5.4.2.1 Software and hardware problems may create the same symptoms but the cause may not be related. To isolate this problem, a list of General and Remote Error messages is supplied in Table 5.14. The general error messages numbered 0 to 9 apply to local and remote operations. The

**Table 5.14 - General and Remote Error Messages**

| Error Message No. | Error Message |
|---|---|
| | GENERAL ERROR MESSAGES |
| 1 | Not in the DC function, 0.1 range when executing DIGITAL ZERO command. |
| 2 | Attempting to execute DIGITAL ZERO command with an input voltage applied or the input open-circuited. Connect a short across input terminals and repeat DIGITAL ZERO command. |
| 3 | The microprocessor's on-board RAM is defective (U35 on the motherboard). |
| 4 | The contents of the non-volatile memory have been disrupted, therefore the instruments calibration should be verified. |
| 5 | A digitizer offset greater than 1000 digits was measured during execution of DIGITAL ZERO command |
| 6 | Percent Deviation of $\geq 10^{10}$% while in the Percent Function. |
| 7 | The RAM is defective, U22 and/or U31 on the motherboard. |
| 8 | An attempt was made to store a overload reading to a register inside the DMM or an attempt was made to store > 99.5959 hours into a Time function register. |
| 9 | An attempt was made to recall a program setting from the program buffer before setting was stored to the program buffer. |
| | GPIB ERROR MESSAGES |
| 10 | Recall of a constant whose value is empty set, for example - sending an "L7" command to a DMM will cause this error if the LOW, AVERAGE, and HIGH constants are the empty set (no readings taken yet.) |
| 11 | Triggered too fast or too often. |
| 12 | Syntax error during GPIB programming. |
| 13 | Option not installed. |

messages numbered 10 to 13 apply to GPIB operation only.

### 5.4.3 Hardware Troubleshooting.

5.4.3.1 To service hardware, it is important to know the normal operation of the DMM. The block diagram in Figure 5.5 is presented as an overview to aid familiarization of the electrical configuration and Figure 5.4 indicates the test point on the parts layout of the mainframe PCB assembly. The schematic drawings in Section 6 complete the necessary details required to troubleshoot the DMM.

5.4.3.2 The DC voltages distributed throughout the DMM are a reliable status indicator and any deviation from normal can be readily observed. Typical operating voltages are supplied in Table 5.15 for the major circuits on the PCB. The left column itemizes the names of the circuits and the instructions are listed across the top. The chart information progresses from left to right. Using the circuit listing 'DIGITAL SUPPLY' for example, it reads:

a. Required voltage column reads +5VA and +5VB.

b. Parts Lay-out Reference Column: A guide to test-point locations.

c. Meter Probe column specifies the test-point connection. It reads Positive TP13 and Negative common TP5.

5.4.3.3 The use of by-pass and decoupling capacitors are numerous through the PCB. A common location for these tors is at the Vcc input to a device. When voltage problems appear in a circuit, checking these capacitors may reduce the search time.

**Table 5.15 - Power Supply Voltage Checks (Page 6-5)**

| Tests → / Circuit ↓ | Required Voltage DC ± 10% | Parts Layout Ref. | Meter Probes Pos. Neg. | Reading OK | Move Probe To → | Move Probe To → | Move Probe To → | AC Reading |
|---|---|---|---|---|---|---|---|---|
| Digital Supply | +5VA | Fig. 5.4 | Pos. TP13<br>Neg. TP5 | No<br>Next→ | U50-IN<br>No → | CR14, Cath.<br>No → | → | Term 7 & 9<br>Power Trans. |
| | +5VB | Fig. 5.4 | Pos. TP14<br>Neg. TP5 | No<br>Next → | U51-IN<br>No → | CR15, Cath.<br>No → | → | Term 7 & 9<br>Power Trans. |
| Non-Voltile Memory | +9V Un-Reg. | Fig. 5.4 | Pos. CR14C<br>Neg. TP5 | No<br>Next → | (Note: When +5VA or B OK, Then +9V OK)<br>→ | | | Term 7 & 9<br>Power Trans. |
| Analog | (+30V) | Fig. 5.4 | Pos. CR22<br>Neg. TP12 | No<br>Next → | CR22, Cathode<br>(+30V) No → | Lower Side R81<br>(+36V) No → | CR20+<br>(+36V) No → | Term 10 & 16<br>Power Trans. |
| Analog | (−30V) | Fig. 5.4 | Pos. CR25<br>Neg. TP12 | No<br>Next → | CR25, Anode<br>(−30V) No→ | Left Side of R82<br>(−36V) No → | CR20−<br>(−36V) No → | Term 10 & 16<br>Power Trans. |
| Isolator | +36V Un-Reg. | Fig. 5.4 | Pos. CR20+<br>Neg. TP12 | No<br>Next → | (Note: When +30V OK, Then +36V OK)<br>→ | | | Term 10 & 16<br>Power Trans. |
| | −36V Un-Reg. | Fig. 5.4 | Pos. CR20−<br>Neg. TP12 | No<br>Next → | (Note: When −30V OK, Then −36V OK)<br>→ | | | Term 10 & 16<br>Power Trans. |
| AC-DC Ohms | +12V Un-Reg. | Fig. 5.4 | Pos. U19 Pin 16<br>Neg. TP12 | No<br>Next → | U48-IN<br>No → | CR-16+<br>No → | → | Term 11 & 15<br>Power Trans. |
| Op-Amps | −15V | Fig. 5.4 | Pos. Can AR6<br>Neg. TP12 | No<br>Next → | No →<br>U49-IN | No →<br>CR16− | → | Term 11 & 15<br>Power Trans |
| Relay Drive | +12V Un-Reg. | Fig. 5.4 | Pos. CR18-Cath.<br>Neg. TP12 | No<br>Next → | No<br>→ | No<br>→ | No<br>→ | Term 12 - 14<br>Power Trans. |
| A-D Converter | +8V | Fig. 5.4 | Pos. U33 Pin 16<br>Neg. TP12 | No<br>Next → | U52-IN<br>No → | → | → | Term 12 - 14<br>Power Trans. |
| Non-Vol Memory Battery | +3V | Fig. 5.4 | Pos. BT1-Pos.<br>Neg. TP12 | No<br>Replace | | | | |
| DC Supply | +5V | Fig. 5.4 | Pos. CR21-Pos.<br>Neg. TP12 | No<br>Next → | Pos. CR14 Cath.<br>+9V. No → | → | → | Terminals 7 &<br>Power Transformer |

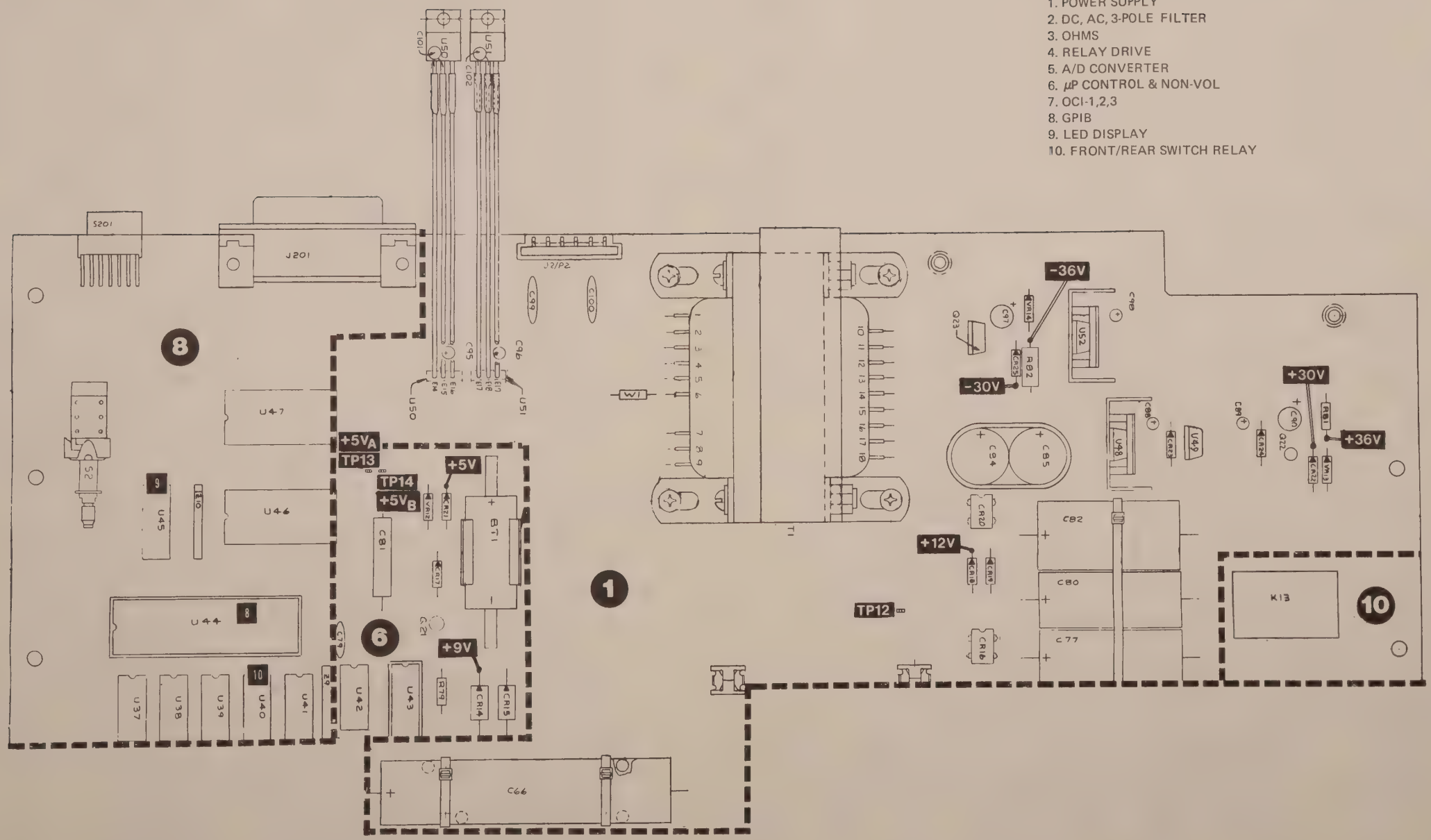



*Figure 5.4 - Test Point Location*

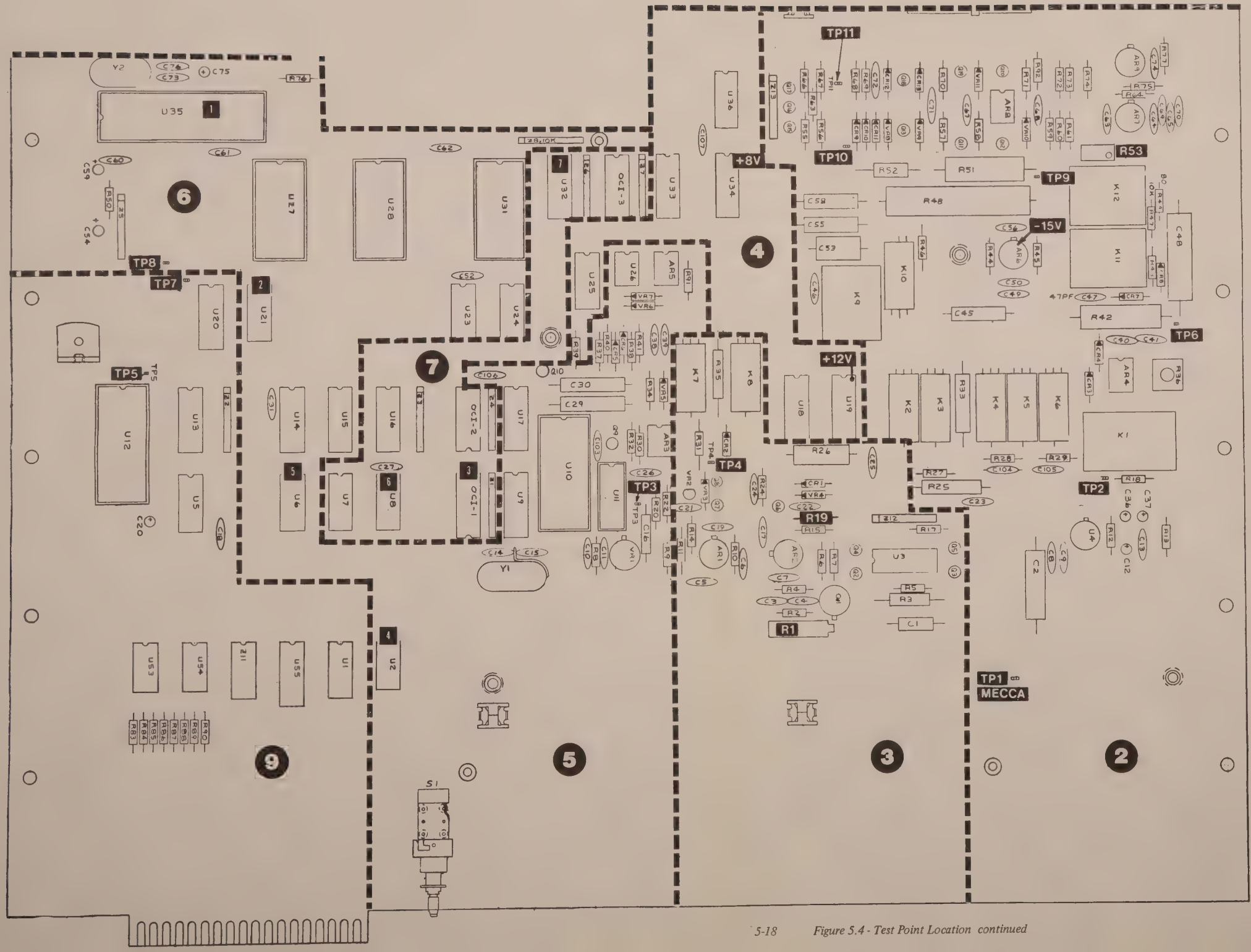





*Figure 5.4 - Test Point Location continued*

5.4.3.4 Troubleshooting Table

5.4.3.4.1 Table 5.16 describes some common failure modes along with their probable cause.

**Table 5.16 - Troubleshooting Examples**

| SYMPTOMS | PROBABLE CAUSE | SUGGESTED CORRECTIONS |
|---|---|---|
| EXAMPLE–A | | |
| DMM displays "5004" during power-up | U20 data buffer may be defective. | Replace U20 |
| DMM displays "5003" during power-up | U28 ROM may be defective. | Replace U28 |
| EXAMPLE–B | | |
| DMM displays model number and/or error message, then fails to proceed. (Hangs-up). | μP unable to control inguard or outguard logic; or μP unable to read from logic using 74LS367-74 L 5175 74 L S175 (U16-U82) buffers. | Scope address decoder outputs U14 pins 15, 14, 13, 12, 11, 10 and 9 or U15 pins 14 and 13. Watch for narrow, negative-going pulses which indicate that the μP is continually waiting for some hardware events or is trying unsuccessfully to initiate a hardware event. The affected address decoder output gives an indication of the hardware involved. |
| EXAMPLE–C | | |
| DMM continues to take readings when in "SINGLE" or "RECALL" mode. | μP receiving non-programmed MNI (non-maskable interrupt) on U35-6<br><br>OR<br><br>loss of "read control" signal somewhere between μP and A/D converter | Verify operation of U2 interrupt and associated circuitry<br><br>Check read control signal as it propagates from U35-15 μP chip through OCI-3 to U10-26 digital control chip. |
| EXAMPLE–D | | |
| Function LED's correspond to selected function but relays don't always change state to match newly selected function. | Defective DC power supply<br><br>OR<br><br>Register Load Hardware (U33-U34) defective. | Alternately press front panel DC and AC keys rapidly and verify the output waveforms from OCI-3 all pins. The signal will swing between 1-1/2 V and 6-1/2 V minimum. They should track the driving waveforms which are partially shown in Table 5.16 Performance tests.<br><br>Also, verify the operation of U32, U33 and U34. Verify the presence of strobe pulse on U33/U34-1 after last clock pulse on U33/U34-3 |

**Table 5.16 - Troubleshooting Examples continued**

| SYMPTOMS | PROBABLE CAUSE | SUGGESTED CORRECTIONS |
|---|---|---|
| EXAMPLE–E | | |
| DMM ignores keyboard. | Key on keyboard is already "pressed" (shorted) | Troubleshoot keyboard rows and columns switch operation |
| | OR | |
| | μP unable to read keyboard status from keyboard three-state buffer. | Verify the operation of U13-keyboard buffer. |
| | OR | |
| | Defective GPIB hardware causes DMM to go to "remote" at power-up | Verify that "remote" LED is not lit after completion of power-up sequence. If LED is lit, replace U44, GPIB. |
| EXAMPLE–F | | |
| "ERROR 5" displayed during digital zero command | U26 - M/2 switch failing to switch AR5-3 to zero volts during digital zero. | Verify a logical '1' on U26-2 during digital zero. If not present, see Example–D, otherwise verify other analog and digital signals on U26. |
| | OR | |
| | A/D converter IC's are suspect | Replace U10 and/or U11. |
| | OR | |
| | A/D output signals lost as they propagate through U17-U9 digitizer drives, OCI-1/2 op-to couplers, and U16 data driver. | Troubleshoot chips, checking for "stuck" levels at each stage. |

**Table 5.17 - 5004 Troubleshooting Table**

| SYMPTOMS | PROBABLE CAUSE | SUGGESTED CORRECTIONS |
|---|---|---|
| DMM displays "5005 or 5006" during power-up | U20 may be defective | Replace U20 |
| DMM displays "5003" during power-up | U28 may be defective | Replace U28 |
| DMM displays Model number and/or error message but then "hangs up" (does not proceed) | $\mu$P unable to control inguard or outguard logic; or $\mu$P unable to read from logic using 74LS367 buffers | Scope address decoder outputs U14-15, 14, 13, 12, 11, 10 & 9 or U15-14,13. Watch for narrow negative-going pulses which indicate that the $\mu$P is continually waiting for some hardware event or is trying unsuccessfully to initiate a hardware event. The affected address decoder output gives an indication of which hardware is involved. |
| DMM continues to take readings when in "HOLD" or "RCL" mode | $\mu$P getting non-maskable interrupts on U35-6<br>OR<br>loss of "read control" signal somewhere between $\mu$P and A/D converter | Verify operation of U2 and surrounding circuitry<br><br>Check read control signal as it propagates from U32-15 through OCI-3 to U10-26 |
| Function LED's correspond to selected function but relays don't always change state to match newly selected function | Bad power supply<br>OR<br>Register load hardware defective | Verify power supplies and replace components as necessary<br><br>Alternately press DC and AC keys at rapid rate and verify proper output waveforms from OCI-3. These signals should swing between 1-1/2V and 6-1/2V as a minimum. They should "track" the driving waveforms which are partially shown in Table 5.16. Also, verify proper operation of U22, U33 and U34. Verify presence of strobe pulse on U33/U34-1 after last clock pulse on U33/U34-3. |

**Table 5.17 - 5004 Troubleshooting Table cond continued**

| SYMPTOMS | PROBABLE CAUSE | SUGGESTED CORRECTIONS |
|---|---|---|
| DMM ignores keyboard | Key on keyboard is always "pressed" (shorted) | OHM-meter all rows and columns of keyboard |
| | OR | |
| | $\mu$P unable to read keyboard status from keyboard tri-state buffer | Verify proper operation of U13 |
| | OR | |
| | Defective GPIB hardware causes DMM to go to "remote" at power-up | Verify that "Remote" LED is not lit after completion of power-up sequence. If so, try replacing U44. |
| "Error 5" displayed during digital zero command or during power-up | U26 not switching zero volts to AR5-3 during digital zero | Verify logical '1' on U26-2 during (and only during) digital zero. If not present, see symptom number 4 above. Otherwise, verify other analog and digital signals on U26 |
| | OR | |
| | A/D converter IC's are bad | Replace U10 and/or U11 |
| | OR | |
| | A/D output signals "lost" as they propagate through U17/U9, OCI1/2 and U16 | Scope signals and check for "stuck" levels at each stage. |

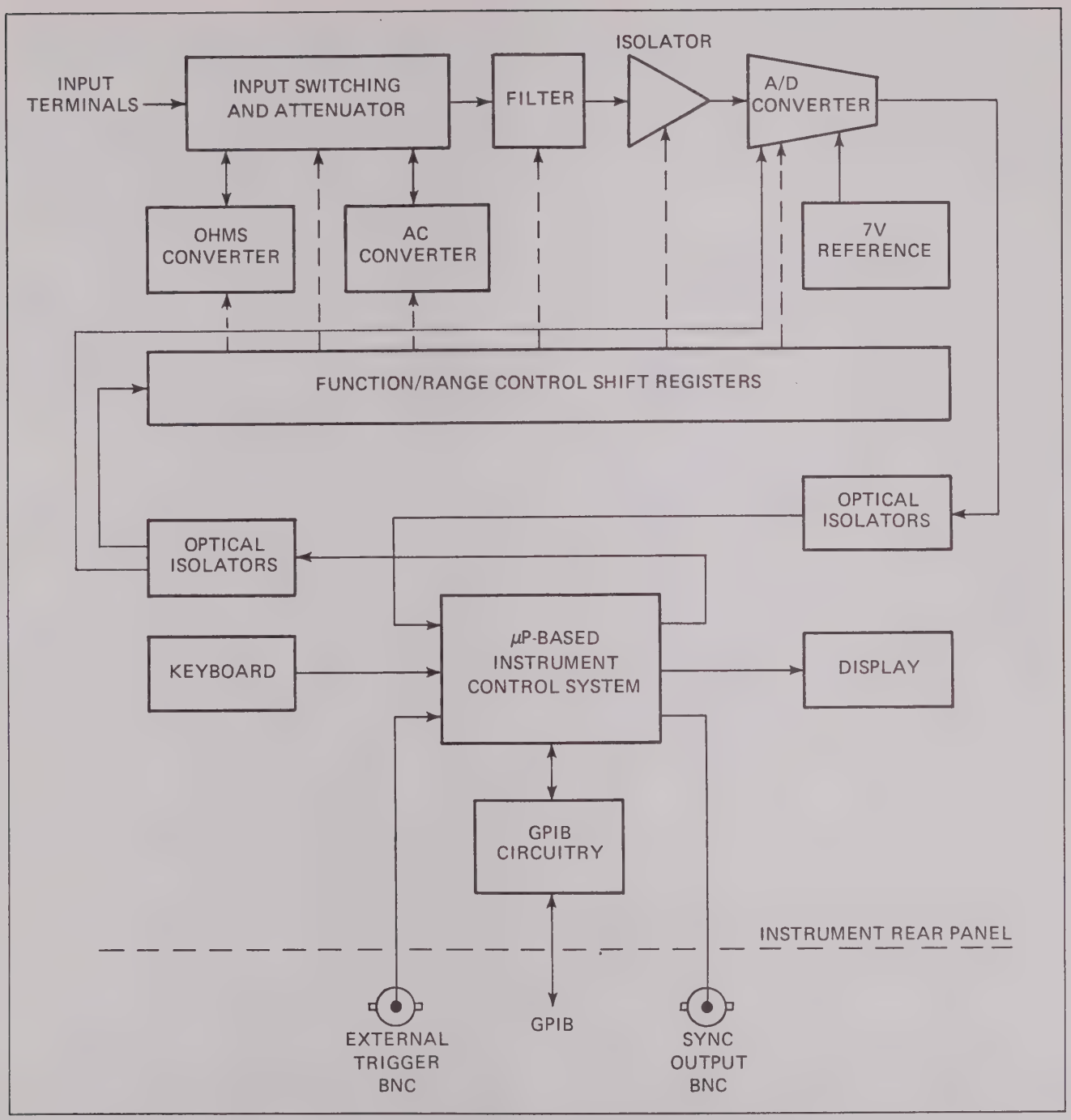



*Figure 5.5 - DMM Block Diagram*

### 5.4.4 Troubleshooting Performance Tests.

5.4.4.1 The unit performance tests are designed to isolate a malfunction to a replaceable module or printed circuit board. In some cases where the printed circuit board is large and complex, the unit test is designed to isolate the malfunction to a functional area of the board.

5.4.4.2 Both the unit and subassembly performance tests present test setup instructions, step by step instructions for monitoring the circuit under test and performance standards in the form of voltage levels or oscilloscope waveforms. For ease in locating the physical test point within the instrument, pictorial drawings are provided.

5.4.4.3 Test points called out in the performance tests may be actual physical test points provided as convenient test points or they may simply be circuit locations such as the end of a resistor or the emitter of a transistor. In either case the test points appear in the performance test tables as black squares.

5.4.4.4 Note that the test points are numbered sequentially from the start of the performance tests and progress to the end. The performance standard for each test point is shown in the table if it is a voltage standard; the waveform standards are provided on waveform illustration pages immediately following the performance test table. The numbered test points refer to square black test point flags **1** appearing on the assembly drawing in the Drawing Section (6).

5.4.4.5 To perform subassembly performance tests refer to the appropriate test table, perform the preliminary test setup presented as the first few steps of the test. When the setup is complete proceed with test and verify that the measurement at each test point is within tolerances called for in the performance standard column of the test. If at any point in the test you do not obtain the required voltage or signal refer to the appropriate schematic to determine the area of the malfunction. Resort to conventional troubleshooting methods to identify the faulty component or circuit. The term conventional troubleshooting methods as used here means checking individual semiconductors, resistors and capacitors in and around the area of malfunction.

**WARNING**

These servicing instructions are for use by qualified personnel only. To avoid electric shock, do not perform any servicing other than that contained in the instructions unless you are qualified to do so.

5.4.4.6 Tables 5.18 through 5.20 present the unit performance tests. Note that the tables contain performance standards for voltage measurements and waveforms. The tolerance required for troubleshooting is looser than operating tolerances because the technician is generally looking for the presence of the signal rather than an exact high tolerance standard. This allows the use of a much broader range of test equipment and also allows the use of test equipment that is not subject to high accuracy calibration requirements.

### 5.4.5 Battery Replacement For Non-Vol Circuit.

5.4.5.1 During power-down periods when the DMM is not AC line powered, a Lithium battery (BT1 located in section 1) maintains the required voltage to the Non-Volatile memory circuit, which includes the CMOS RAM U43. When the voltage drops below 2.3V, the RAM will lose its CAL constants. This causes the "ERROR 4" message to be displayed next time the DMM is powered-up.

5.4.5.2 It is important to recognize that the displayed error message indicates that the contents of the Non-Vol memory were disrupted and most often indicates a discharged battery. If the battery voltage to U43-16 with power-down exceeds 2.3V, other components in the circuit may be at fault.

5.4.5.3 STEPS TO REPLACE BT1 BATTERY.

a) Apply power to the DMM. Verify that it completes the power-up sequence listed in paragraph 3.2.2.

**WARNING**

During removal of the bottom guard-shield plate, care must be taken that the non-volatile memory battery supply (BT-1) is not short-circuited, losing all CAL constants stored in memory. When the guard-shield is freed, lift directly away from or at right-angle (orthogonal) to the PCB. Do not slide the shield over the PCB.

b) CAUTION: The DMM is still powered-up. Use an un-grounded soldering iron to unsolder the battery tabs from the motherboard and remove the old battery.

c) Observe polarity and install the new battery in the same position.

**WARNING**

Lithium batteries may explode if short-circuited, recharged, disassembled, heated or disposed of in fire. Battery leakage may forewarn the problem.

5.4.5.4 Preventative Maintenance: Use the following procedure to check the battery condition:

a) Turn-off the AC power to the DMM.

b) Wait 30 seconds.

c) Measure the voltage drop with a one millivolt resolution DVM across R80, the 1 Kohm resistor in series with the battery.

d) The voltage drop across R80 should be less than 20 mV (battery drain 20 $\mu$A).

5.4.5.5 Suggested Battery Replacement Interval can be determined from Figure 5.6. It is supplied as an aid to determine how often the Lithium battery, BT1, should be replaced. Notice that the worst-case battery drain occurs if the instrument is stored at high temperatures with the power off (3 year replacement interval). For most applications, a 4 year replacement interval is suggested.

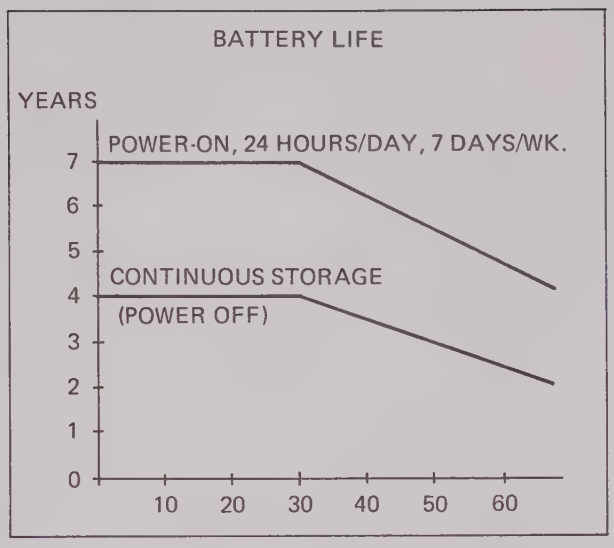



*Figure 5.6 - Average Ambient Temperature ($^{o}C$)*

**Table 5.18 - Digital Section Performance Test**

| Input and Control Setting | Signal Nomenclature | Reference Designation | Test Point | Illustration Reference | Performance Standard |
|---|---|---|---|---|---|
| Using conventional techniques, the Digital Section can only be tested to the point where certain "Knowns" can be verified. If the proper waveforms are not observed, the nearest Racal-Dana serivce center should be contacted. | | | | | |
| All measurements in this table are referenced to TP4, Digital Common. Power Switch: ON | | | | Test Points Shown on Figure 5.4 | |
| Disconnect any cables connected to Rear Panel GPIB and BNC Connectors | +5 VA<br>+5 VA<br>+5 VB<br>$\overline{\text{Reset}}$<br>$\overline{\text{NMI}}$ | U35 Pin 40<br>U35 Pin 6 | 1<br>1 | | +5V ± .25 VDC<br>+5V ± .25 VDC<br>+5V ± .25 V<br><br>+2.5V to +5.25V with no excursions below +2.5V |
| Set Scope Trigger To Internal, Channel 1, + Slope | $\mu$P Clock E | U21 Pin 11 | 2 | | Waveforms #7, Ch. 1 |
| | Inverse Signal $\overline{\text{E}}$ | U21 Pin 10 | 2 | | Waveforms #7, Ch. 2 |
| | Address Bus | U35 Pins 9 to 20 and 22 to 25 | 1 | | See Note Below |
| | Data Bus | U35 Pins 26 to 33 | 1 | | See Note Below |
| | VMA | U35 Pin 5 | 1 | | See Note Below |
| | R/$\overline{\text{W}}$ | U35 Pin 34 | 1 | | See Note Below |
| | W/$\overline{\text{R}}$ | U21 Pin 8 | 2 | | See Note Below |
| Scope Trigger Set To: Internal, + Slope, Channel 1 | Digit Strobe Sync D6 (After Opto-isolation) | OCI1 Pin 11 | 3 | | Waveforms #2, Ch. 1 |
| | 1 KHz (After Opto-isolation) (approx. .83 KHz in 50 Hz Machine) | OCI1 Pin 14 | 3 | | Waveforms #2, Ch. 2 |
| | | | | | |

Note: These waveforms are asynchronous TTL signals. If the signals are always high or low at this point, it is an indication of a Fault.

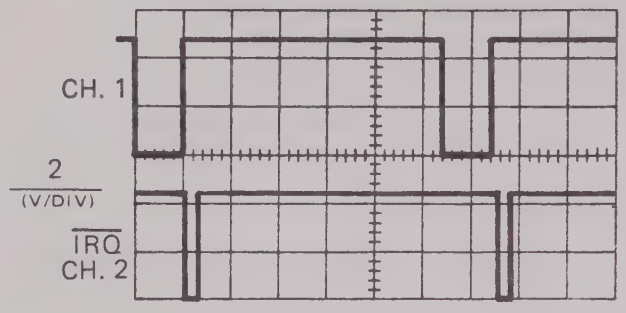
**Table 5.18 - Digital Section Performance Test continued**

| Input and Control Setting | Signal Nomenclature | Reference Designation | Test Point | Illustration Reference | Performance Standard |
|---|---|---|---|---|---|
| Instrument in "Hold" Mode (Press "SINGLE" Key on Keyboard)<br><br>Scope Trigger Set To: Internal, – Slope, Channel 1 | Clock to Interrupt - Control FF | U2 Pin 11 | 4 | | Waveforms #1, Ch. 1 |
| | $\overline{IRQ}$ Input to $\mu P$ | U35 Pin 4 | 1 | | Waveforms #1, Ch. 2 |
| Instrument in "Hold" mode (Press "SINGLE" Key on Keyboard)<br><br>Scope Trigger Set To: Internal, – Slope, Channel 1 | $\overline{DSPE}$ | U6 Pin 8 | 5 | | Waveforms #5, Ch. 1 |
| DMM Set to Internal Trigger (Press "Track" Key)<br>4 1/2 Digit Mode (Toggle "RESOL" Key if required)<br><br>Scope Trigger Set To: Internal, + Slope, Channel 1 | $\overline{\text{End of Conversion}}$ (After Opto-isolation and Schmitt Trigger Inversion) | U8 Pin 11 | 6 | | Waveforms #4, Ch. 1 |
| | Rdg Rdy (Reading Ready) | U8 Pin 9 | 6 | | Waveforms #4, Ch. 2 |
| DMM Set to Internal Trigger (Press "Track" Key)<br>4 1/2 Digit Mode (Toggle "RESOL" Key if required) | Sync Output | Sync Output BNC (Rear Panel) | Rear Panel BNC | | Waveform #3 |
| Scope Trigger Set To: Internal, – Slope, Channel 1<br><br>Alternately Press "10" and "100" Range Keys at a Rapid Rate<br><br>Scope Trigger Set To: Internal, + Slope, Channel 1 | CLK | U32 Pin 7 | 7 | | Waveforms #6, Ch. 1 |
| | Strobe | U32 Pin 2 | 7 | | Waveforms #6, Ch. 2 |

Table 5.18 - Digital Section Performance Test continued

1
(NO.)

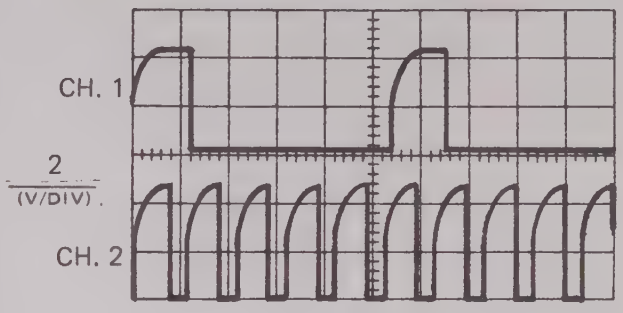
SEE NOTE 1




1mS
(S/DIV)

2
(NO.)

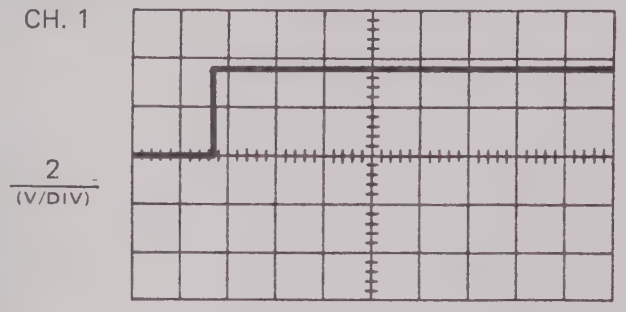
SEE NOTE 1




1mS
(S/DIV)

3
(NO.)

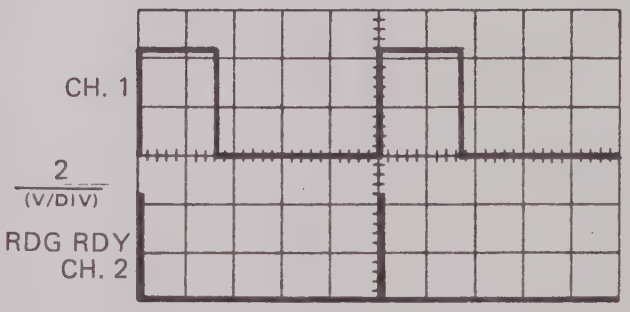
REAR PANEL SYNC OUTPUT PULSE




2μS
(S/DIV)

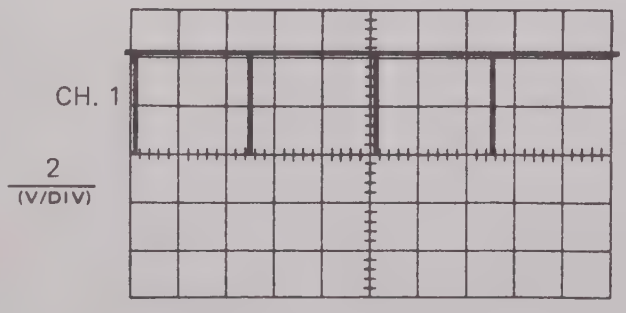
4
(NO.)

SEE NOTE 1



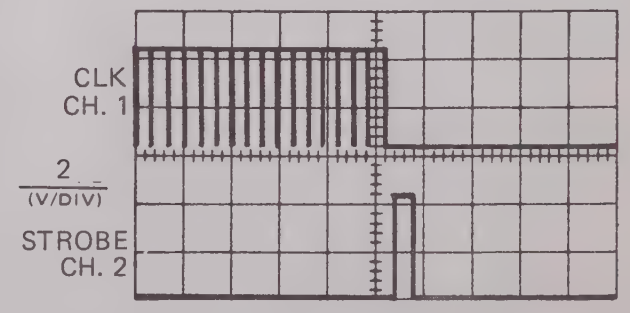

5mS
(S/DIV)

5
(NO.)




5mS
(S/DIV)

6
(NO.)




2mS
(S/DIV)

NOTE 1 WAVEFORMS ARE SHOWN FOR A 60 Hz UNIT. WAVEFORMS TAKEN FROM A 50 Hz UNIT WILL BE 10% LOWER IN FREQUENCY.

**Table 5.18 - Digital Section Performance Test continued**

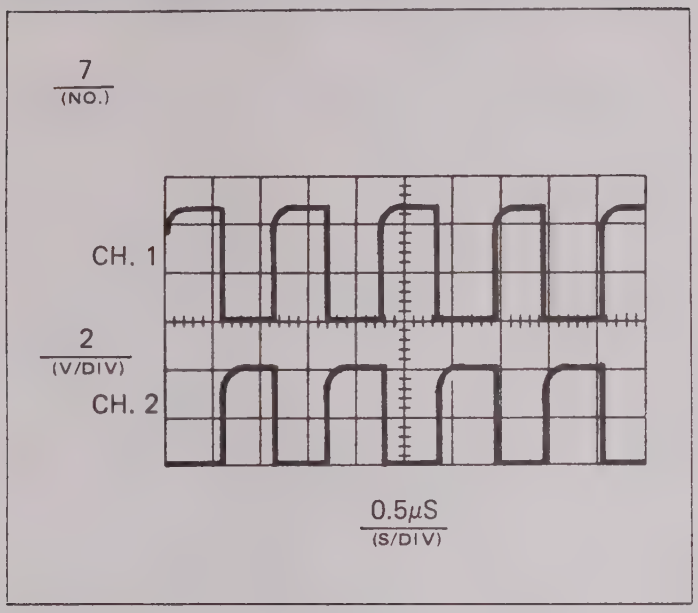


**Table 5.19 - GPIB Performance Test**

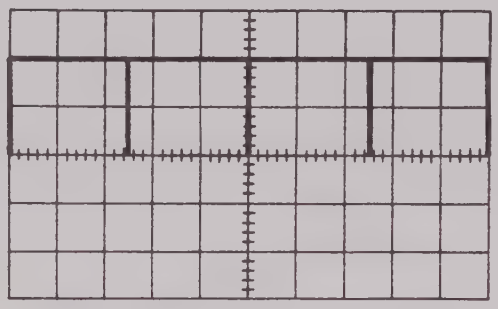
| Input and Control Setting | Signal Nomenclature | Reference Designation | Test Point | Illustration Reference | Performance Standard |
|---|---|---|---|---|---|
| Set All Rear Panel GPIB Switches to their Lower Position.<br><br>Turn DMM's Power Off and then On again. | All measurements in this table are referenced to TP4, Digital Common. | | | | |
| Disconnect all Cables from GPIB Connector | GPIB Data/Control Lines | J201 Pins 1-11 and Pins 13-17 | | Rear Panel Connector | +2.5 to +3.7V |
| | 68488 GPIB I/O Lines | U44 Pins 16-23, Pins 25,26 Pins 29-36 | 8 | | +2.5 to +5.25V |
| DMM in "HOLD" Mode (Press "SINGLE" Key)<br><br>Set Scope Trigger to Internal, – Slope, Channel 1 | $\overline{ASE}$ | U45 Pin 1 and/or Pin 15 | 9 | | GPIB Waveform # 1 |
| DMM set to Internal Trigger (Press "Track" Key)<br>4 1/2 Digit Mode (Toggle "RESOL" Key if necessary)<br>Talk Only (Set Rear Panel "talk only" Switch to "up" position)<br>Set Scope Trigger to Internal, + Slope, Channel 1 | Momentary Output Holdoff Pulse from $\mu$P<br><br>(1 per Reading) | U39 Pin 8 | 10 | | GPIB Waveform # 2 |

**Table 5.19 - GPIB Performance Test continued**

| Input and Control Setting | Signal Nomenclature | Reference Designation | Test Point | Illustration Reference | Performance Standard |
|---|---|---|---|---|---|
| DMM Set to Internal Trigger (Press "Track" Key)<br>4 1/2 Digit Mode (Toggle "RESOL" Key if necessary)<br>Talk Only (Set Rear Panel "talk only" Switch to "up" position)<br>Set Scope Trigger to Internal, + Slope, Channel 1 | RFD | U44 Pin 18 | 8 | | GPIB Waveform # 3 |
| DMM Set to Internal Trigger (Press "Track" Key)<br>4 1/2 Digit Mode (Toggle "RESOL" Key if necessary)<br>Talk Only (Set Rear Panel "talk only" Switch to "up" position)<br>Set Scope Trigger to Internal, + Slope, Channel 1 | RFD<br>$\overline{\text{GPIRQ}}$ | U44 Pin 18<br>U44 Pin 40 | 8 | | GPIB Waveform # 4 Channel 1<br>GPIB Waveform # 4 Channel 2 |

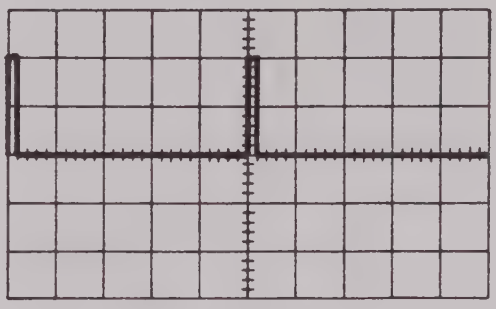
Table 5.19 - GPIB Performance Test continued

1 (NO.)



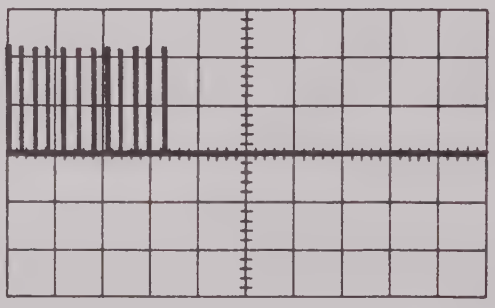

5mS (S/DIV)

2 (NO.)



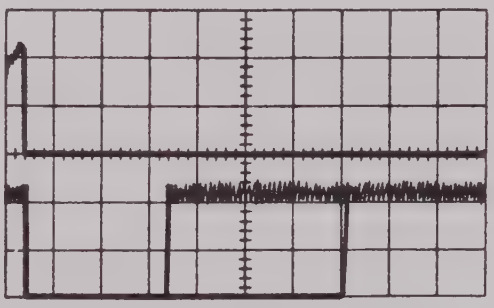

5mS (S/DIV)

3 (NO.)




0.5mS (S/DIV)

4 (NO.)




10μS (S/DIV)

**Table 5.20 - Digitizer Performance Test**

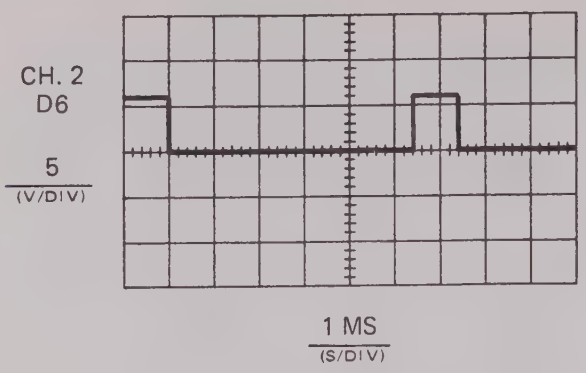
| Input and Control Setting | Signal Nomenclature | Reference Designation | Test Point | Illustration Reference | Performance Standard |
|---|---|---|---|---|---|
| All measurements made in this table referenced to "Mecca" TP1.<br><br>Instrument in 0.1V Range DC,input shorted. Internal Trig. (Hit "Track" Key)<br><br>Scope Trigger set to: Ch. 2, +, internal | D1 - D5 | U10 Pins 3-8 | | | Waveforms # 2-6 |
| | D6 | U10 Pin 8 | | | Waveform # 1 |
| Instrument in 0.1V Range DC,input shorted. Internal Trig. (Press "Track" Key)<br><br>Scope Trigger set to: Ch. 1, +, internal | 1 KHz Clock | U10 Pin 28 | | | Waveform # 7 |
| Instrument in 0.1V Range DC, input shorted, internal trigger (Press "Track" Key)<br><br>Scope trigger set to: Ch. 1, +, internal | 2.5 MHz Clock | U10 Pin 14 | | | Waveform # 8 |
| Instrument in 0.1V Range DC, input shorted, internal trigger (Press "Track" Key)<br><br>Scope Trigger set to: Normal, +, internal | E.O.C. | U10 Pin 19 | | | Waveform # 9 |
| Instrument in 0.1V Range DC, input shorted, internal trigger (Press "Track" Key)<br><br>Scope Trigger set to: Normal, +, internal | M.Z. | U10 Pin 20 | | | Waveform # 10 |
| Instrument in 1V Range DC, +2V in internal trigger (Press "track" key)<br><br>Scope Trigger set to: Normal, –, internal | M.Z. Switch | U26 Pin 4 | | | Waveform # 11 |
| Instrument in 1V Range DC, –2V in internal trigger (press track key)<br><br>Scope trigger set to: Normal, +, internal | M.Z. Switch | U26 Pin 4 | | | Waveform # 12 |

**Table 5.20 - Digitizer Performance Test continued**

| Input and Control Setting | Signal Nomenclature | Reference Designation | Test Point | Illustration Reference | Performance Standard |
|---|---|---|---|---|---|
| Instrument in .1V Range DC, input shorted, internal triggered (Press "track" key)<br><br>+ probe on:<br>–probe on: | A-D Converter Reference Voltage | <br><br>U11, Pin 10<br>Mecca TP-1 | | | <br><br>+7V ± 0.4V |
| Instrument in 0.1V Range DC, input shorted, internal trigger (Press "Track" Key)<br><br>+ Probe on:<br>–probe on: | $V_{STRG}$ (Auto-Zero Voltage) | <br><br>AR3, pin 6 | | | <br><br>–2.6V ± 1V |

Table 5.20 - Digitizer Performance Test continued

1 (NO.)

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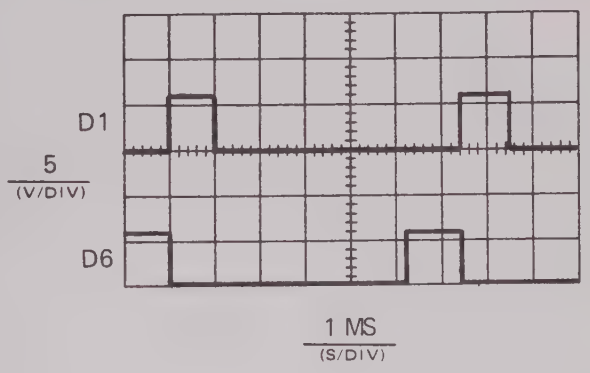


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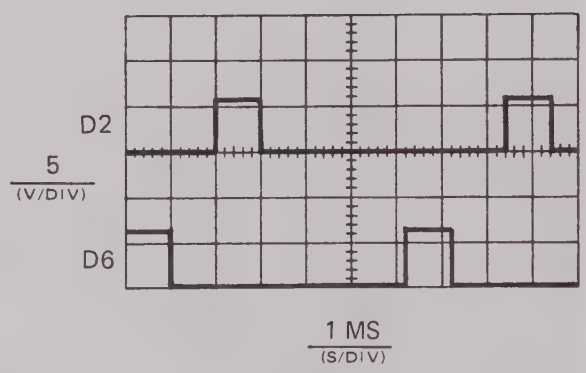


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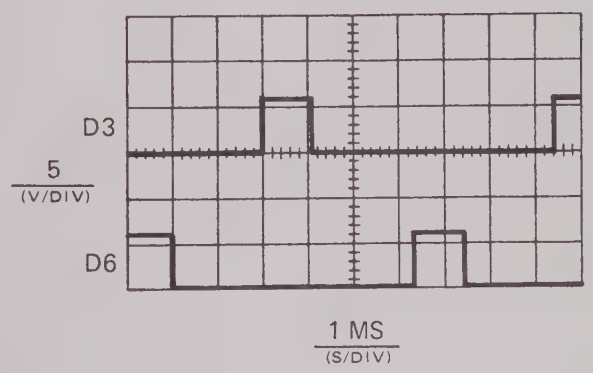


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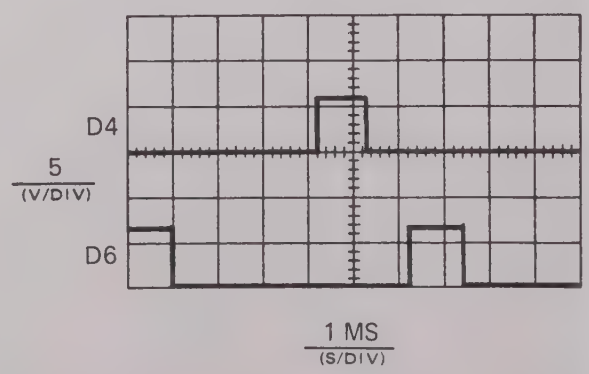


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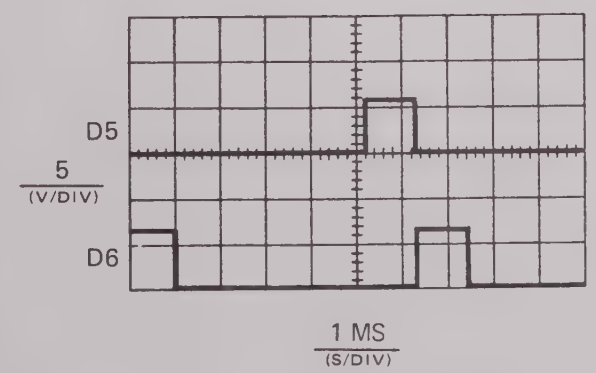
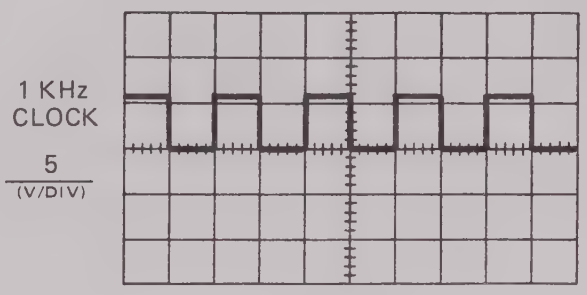
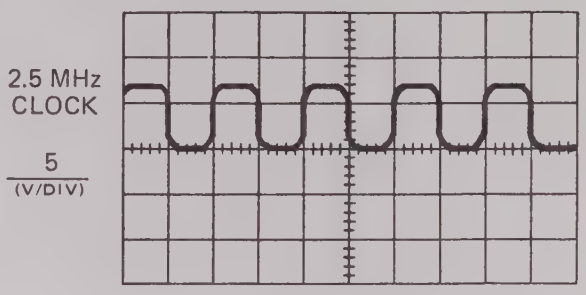


Table 5.20 - Digitizer Performance Test continued

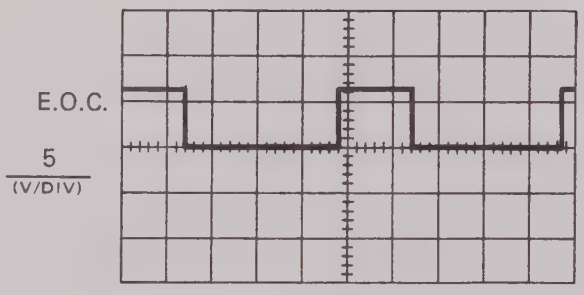
7 (NO.)



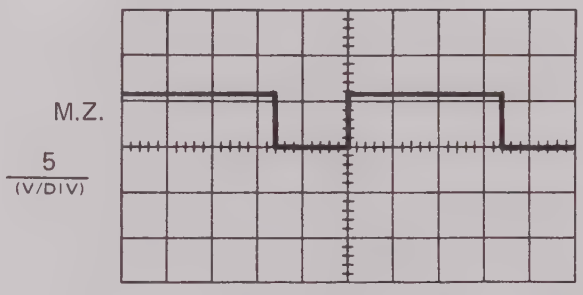

8 (NO.)




9 (NO.)




10 (NO.)

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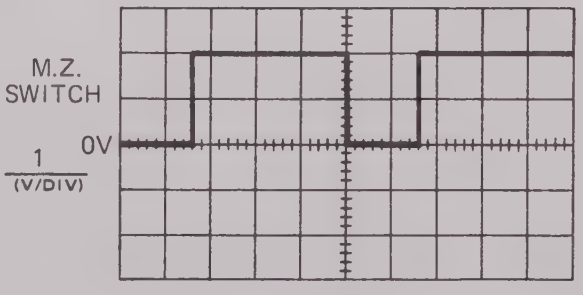
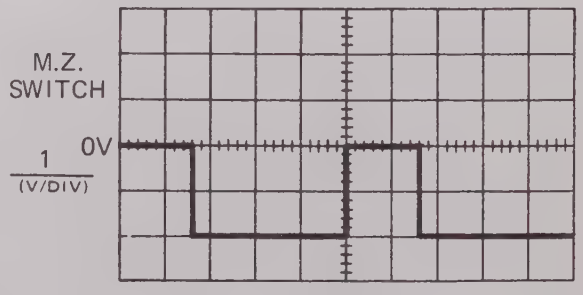



12 (NO.)



# SECTION 6 DRAWINGS & PARTS LIST


| Title | Page |
|---|---|
| Chassis Assembly (404085A) (Front Panel 404087-A & Rear Panel 404086-A) | 6-2 |
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| Power Supply | 6-9 |
| DC, AC, 3-Pole Filter | 6-13 |
| Ohms | 6-17 |
| Relay Drive | 6-19 |
| A/D Converter | 6-21 |
| $\mu$P Control, Non Vol | 6-23 |
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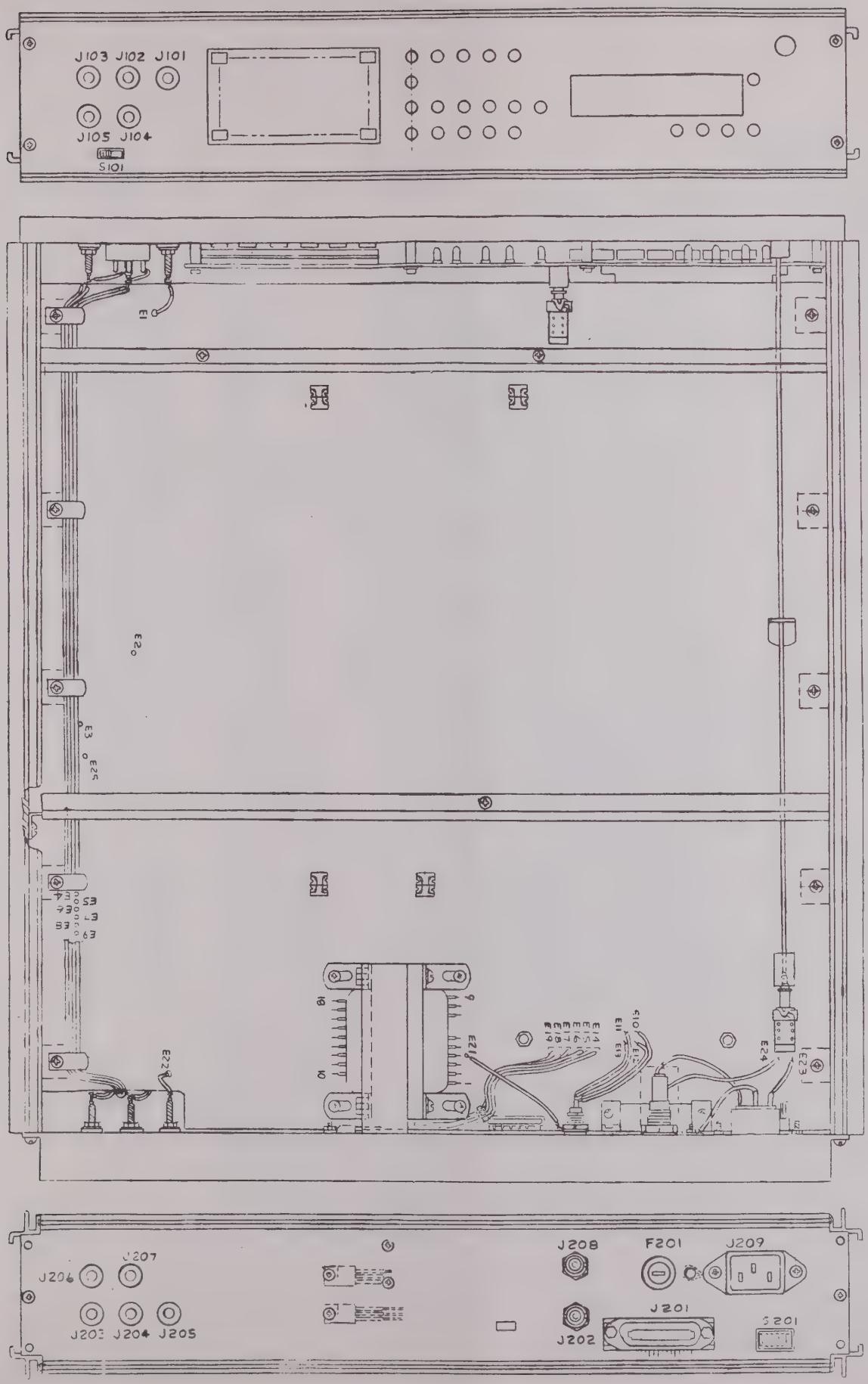
| F/R Switch | 6-32 |

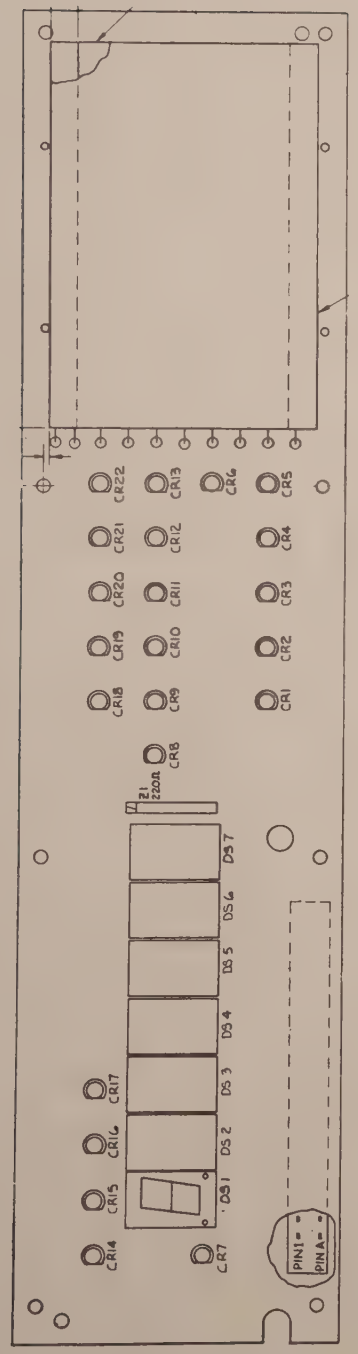
404085 – CHASSIS ASSEMBLY

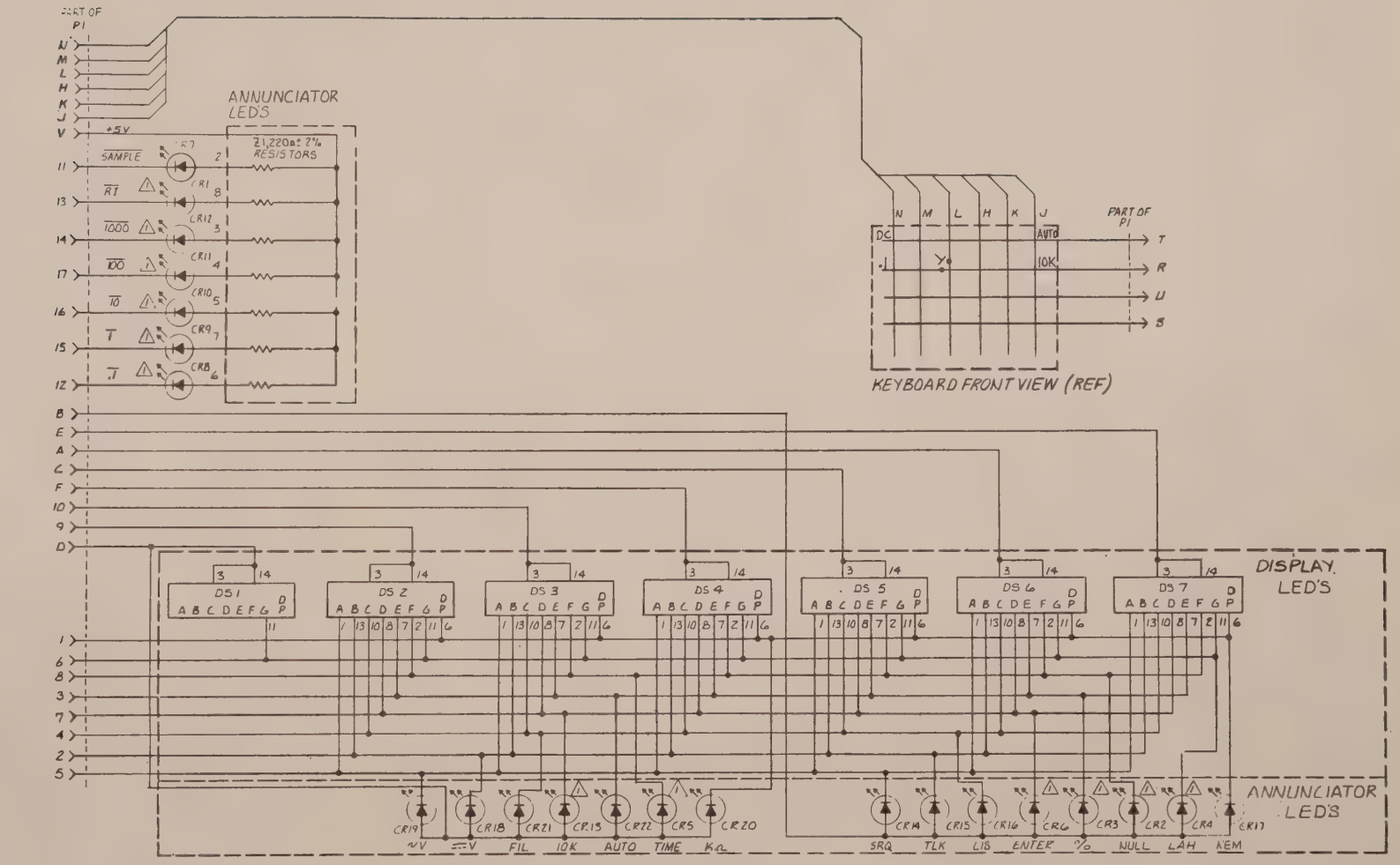
| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| F201 | 920204 | FUSE SLO .50 A (100V, 120V Operation) | 75915 | 3AG1/2ASB |
| | 920802 | FUSE SLO .25 A (220V, 240V Operation) | 75915 | 213.250 |
| J101 | 600980 | POST BINDING, BANANA JACK, BLACK | 05276 | 2854-0 |
| J102 | 600980 | POST BINDING, BANANA JACK, BLACK | 05276 | 2854-0 |
| J103 | 600980 | POST BINDING, BANANA JACK, BLACK | 05276 | 2854-0 |
| J104 | 600989 | POST BINDING, BANANA JACK, WHITE | 05276 | 2854-9 |
| J105 | 600989 | POST BINDING, BANANA JACK, WHITE | 05276 | 2854-9 |
| J201 | 600957 | RECEPT 24 POS | 00779 | 552791-1 |
| J202 | 600808 | CONN BNC | 02660 | 31-010 |
| J203 | 600980 | POST BINDING, BANANA JACK, BLACK | 05276 | 2854-0 |
| J204 | 600980 | POST BINDING, BANANA JACK, BLACK | 05276 | 2854-0 |
| J205 | 600980 | POST BINDING, BANANA JACK, BLACK | 05276 | 2854-0 |
| J206 | 600989 | POST BINDING, BANANA JACK, WHITE | 05276 | 2854-9 |
| J207 | 600989 | POST BINDING, BANANA JACK, WHITE | 05276 | 2854-9 |
| J208 | 600808 | CONN BNC | 02660 | 31-010 |
| J209 | 600619 | CONN RECPTLE | 82389 | EAC-301 |
| S201 | 600814 | SWITCH 6 SPST | 11237 | 206-6 |


J103 J102 J101
J105 J104
S101
E1
E2
E3
E23
E22
E21
E24
J206
J207
J203 J204 J205
J208
F201
J209
J202
J201
S201

401643 – Assy., PCB, DISPLAY

| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| CR1 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR2 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR3 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR4 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR5 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR6 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR7 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR8 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR9 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR10 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR11 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR12 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR13 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR14 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR15 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR16 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR17 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR18 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR19 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR20 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR21 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| CR22 | 210072 | LAMP HI EFFICIENCY, YELLOW - SOLID STATE | 50434 | HP5082-4550 |
| DS1 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| DS2 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| DS3 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| DS4 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| DS5 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| DS6 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| DS7 | 210074 | DIODE 7-SEGMENT LED DISPLAY, YELLOW | 50434 | HP5082-7660 |
| P1 | 600228 | CONN 18 P | 71785 | 252-18-30-160 |
| Z1 | 080000 | RES CERMET 200 OHM Network 8P,7R 2% | 11236 | 750-81-R220Ω |




3 CR1 THRU CR22 ARE 210072.

2 DS1 THRU DS7 ARE 10074.

△ CR1-CR6 AND CR8-CR13 DELETED FOR MODEL 5009.

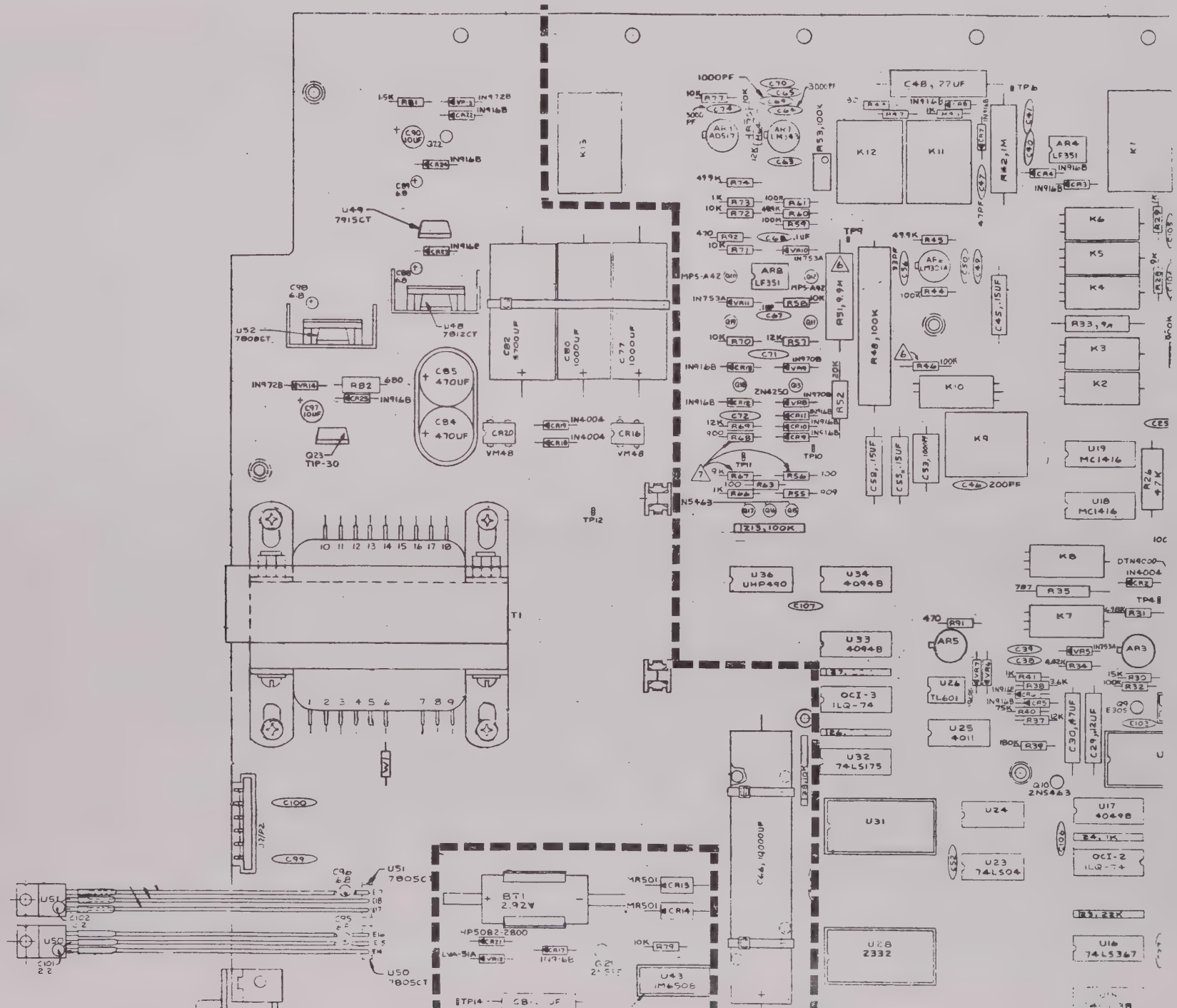
NOTES: UNLESS OTHERWISE SPECIFIED

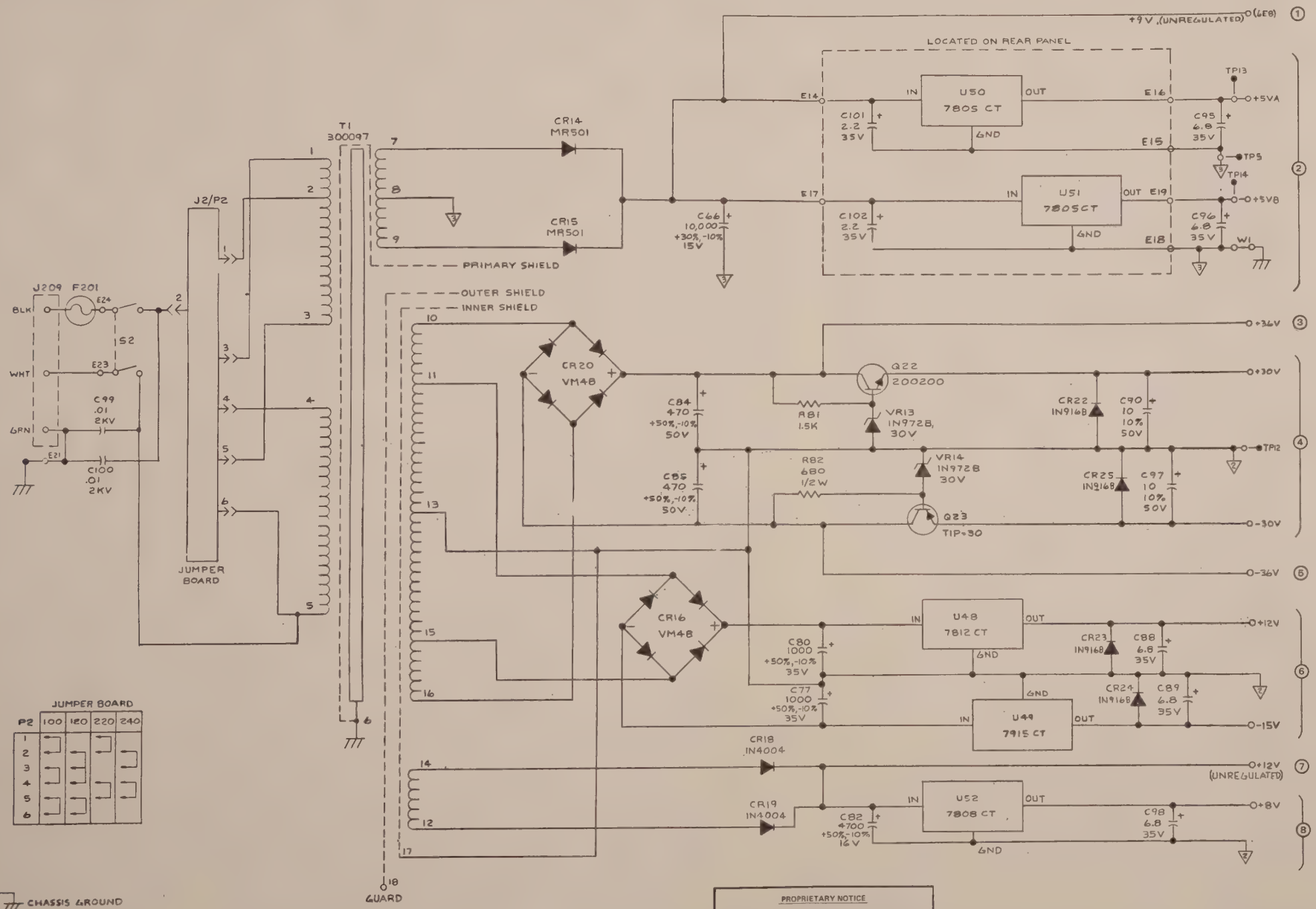
401642 – Assy., PCB, MOTHERBOARD (POWER SUPPLY)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| C66 | 110174 | CAP | ELECT | 10.000 MFD | 15 V | | | 3050HS1030015244G |
| C77 | 110192 | CAP | ELECT | 1000 MFD | 35 V | | | 35TAL1000 |
| C80 | 110192 | CAP | ELECT | 1000 MFD | 35 V | | | 35TAL1000 |
| C82 | 110185 | CAP | ELECT | 4700 MFD | 16 V | | | 16TAL4700 |
| C84 | 110194 | CAP | ELECT | 470 MFD | 50 V | Radial Lead | | See Description |
| C85 | 110194 | CAP | ELECT | 470 MFD | 50 V | Radial Lead | | See Description |
| C88 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C89 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C90 | 110158 | CAP | TANTA | 10 MFD | 50 V | 10% | 05397 | T362C106K050A |
| C95 | 110126 | CAP | TANTA | 6.8 MFD | 35 v | 20% | 05397 | T368B685M035AS |
| C96 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C97 | 110158 | CAP | TANTA | 10 MFD | 50 V | 10% | 05397 | T362C106K050A |
| C98 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C99 | 100111 | CAP | CERAM | .01 MFD | 2000 V | | 71471 | HVD6-2KV |
| C100 | 100111 | CAP | CERAM | .01 MFD | 2000 V | | 71471 | HVD6-2KV |
| C101 | 110125 | CAP | TANTA | 2.2 MFD | 35 V | 20% | 05397 | T368B225M035AS |
| C102 | 110125 | CAP | TANTA | 2.2 MFD | 35 V | 20% | 05397 | T368B225M035AS |
| CR14 | 210070 | DIODE | POWER | 3 AMP | | | 04713 | MR501 |
| CR15 | 210070 | DIODE | POWER | 3 AMP | | | 04713 | MR501 |
| CR16 | 230465 | IC | DIODE BRIDGE | | | VM48 | 27777 | VM48 |
| CR18 | 210004 | DIODE | SILICO | | | | 81349 | 1N4004 |
| CR19 | 210004 | DIODE | SILICO | | | | 81349 | 1N4004 |
| CR20 | 230465 | IC | DIODE BRIDGE | | | VM48 | 27777 | VM48 |
| CR22 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR23 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR24 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR25 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| P2 | 410727 | PCB ASSY | | LINE VOLTAGE SELECTOR | | | 21793 | 410727 |
| Q22 | 200200 | TRANS | NPN | | | | 21793 | 200200 |
| Q23 | 200139 | TRANS | POWER | | | | 01295 | TIP30 |
| R81 | 000152 | RES | CARBON | 1.5 K | | 5% 1/4W | 81349 | RC07GF152J |
| R82 | 001874 | RES | CARBON | 680 OHM | | 5% 1/2W | 81349 | RC20GF681J |
| S2 | 600975 | SWITCH, PUSHBUTTON | | | | | 71590 | SPEC PB12.5 |

401642 – Assy., PCB, MOTHERBOARD (POWER SUPPLY) continued

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|
| T1 | 300097 | TRANS | POWER | | | CMI-2570 |
| U48 | 230200 | IC | + 12 VOLT REGULATOR | | 04713 | MC7812-CP |
| U49 | 230378 | IC | -15 VOLT REGULATOR | | 27014 | 7915CT |
| U50 | 230275 | IC | + 5 VOLT REGULATOR | | 04713 | MC7805CT |
| U51 | 230275 | IC | + 5 VOLT REGULATOR | | 04713 | MC7805CT |
| U52 | 230463 | IC | + 8 VOLT REGULATOR | | 04713 | MC7808CT |
| VR13 | 220088 | DIODE | ZENER | 30 V | 04713 | 1N972B |
| VR14 | 220088 | DIODE | ZENER | 30 V | 04713 | 1N972B |
| W1 | 600245 | JUMPER | INSULATED | | | L-2007-1LP |


U49 7915CT
U52 7808CT
U48 7812CT
C98 68
C90 1000UF
C88 68
C82 4700UF
C80 1000UF
C77 1000UF
C85 470UF
C84 470UF
C97 10UF
Q23 TIP-30
RB2 680
CR20 VM48
CR16 VM48
IN4004
TP12
T1
U36 UHP490
U34 4094B
U33 4094B
OCI-3 ILQ-74
U32 74LS175
U31
U24
U23 74LS504
U28 2332
U43 IM6508
U17 4049B
OCI-2 ILQ-74
U16 74LS367
U25 4011
U26 TL601
AR5
AR3
Q10 2N5463
C30, 47UF
C29, .12UF
C100
C99
C96 68
U51 7805CT
U50 7805CT
BT1 2.92V
MR5001
CR15
CR14
MPS082-2800
CR21
C66, 14000UF
C102 22
C101 22
C95
C21
BTP14
C48, 77UF
K13
K12
K11
K1
K6
K5
K4
K3
K2
K10
K9
K8
K7
AR4 LF351
AR8 LF351
AR1 ADS17
AR1 LM363
AR1A LM301A
R42, 1M
R53, 100K
R51, 9.9M
R48, 100K
R52
R33, 9K
R26 47K
R35
R31
R30
R32
R34
R38 3.6K
R40
R37
R39
R91
C45, .15UF
C58, .15UF
C55, .15UF
C53, 1000PF
C46 200PF
U19 MC1416
U18 MC1416
Z13, 100K
DTN9C00
IN4004
IN9728
IN9168
IN753A
MPS-A42
ZN4250
IN5463
TP1
TP2
TP3
TP4
TP5
TP6
TP7
TP8
TP9
TP10
TP11




1. NON-VOL MEMORY
2. DIGITAL
3. ISOLATOR
4. ISOLATOR/OHMS CURRENT SOURCE
5. ISOLATOR
6. AC/DC OHMS
7. RELAY DRIVE
8. A-D CONVERTER

| | |
|---|---|
| C107 | C28, 32-35, 42-44, 51, 57, 78, 83, 85, 87, 91-94 |
| Z13, | |
| VR14 | VR3 |
| U55 | U22, 29, 30 |
| TP14 | |
| T1 | |
| S201 | |
| S2 | |
| R93 | R16, 21, 33, 44, 54, 62, 65, 75 |
| CR23 | CR14 |
| OC-3 | |
| V13 | |
| J201 | |
| J2/P2 | |
| CR25 | |
| E27 | |
| BT1 | |
| AR° | |
| LAST | NOT USED |

DESIGNATORS

JUMPER BOARD

| P2 | 100 | 120 | 220 | 240 |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |
| 5 | | | | |
| 6 | | | | |

CHASSIS GROUND
DIGITAL GROUND
ANALOG COMMON
REFERENCE COMMON (MECCA)

3. RESISTOR NETWORKS ± 2%.
2. CAPACITORS ARE IN MF, ± 20%, 100V
1. RESISTORS ARE IN OHMS, ± 5%, 1/4W
NOTES: UNLESS OTHERWISE SPECIFIED FOR PAGES 1-11.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# SCHEMATIC - MOTHERBOARD

| SIZE | CODE IDENT NO. | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 431642 | J |

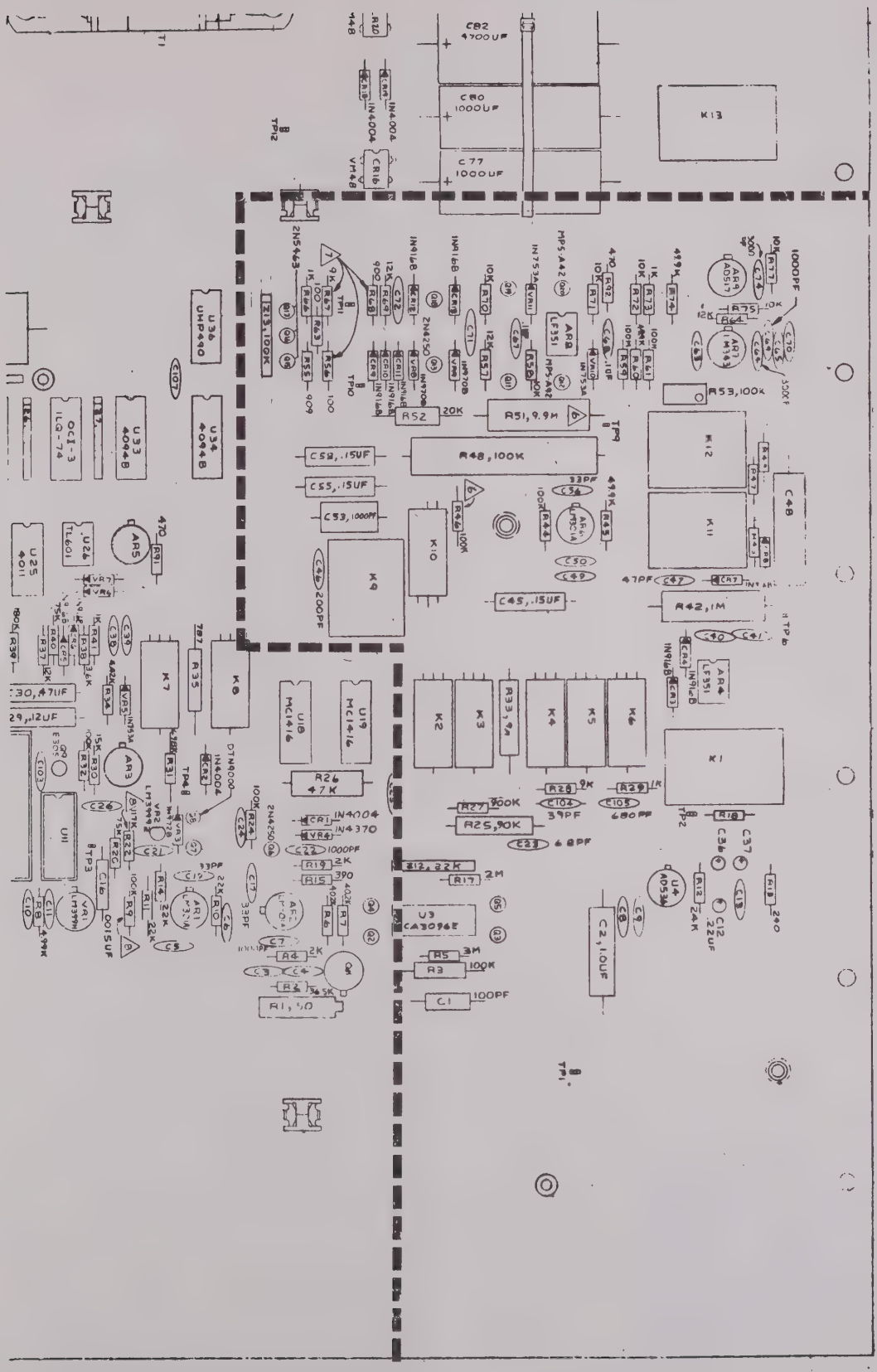
SCALE NONE — SHEET 1 OF 11

6-9

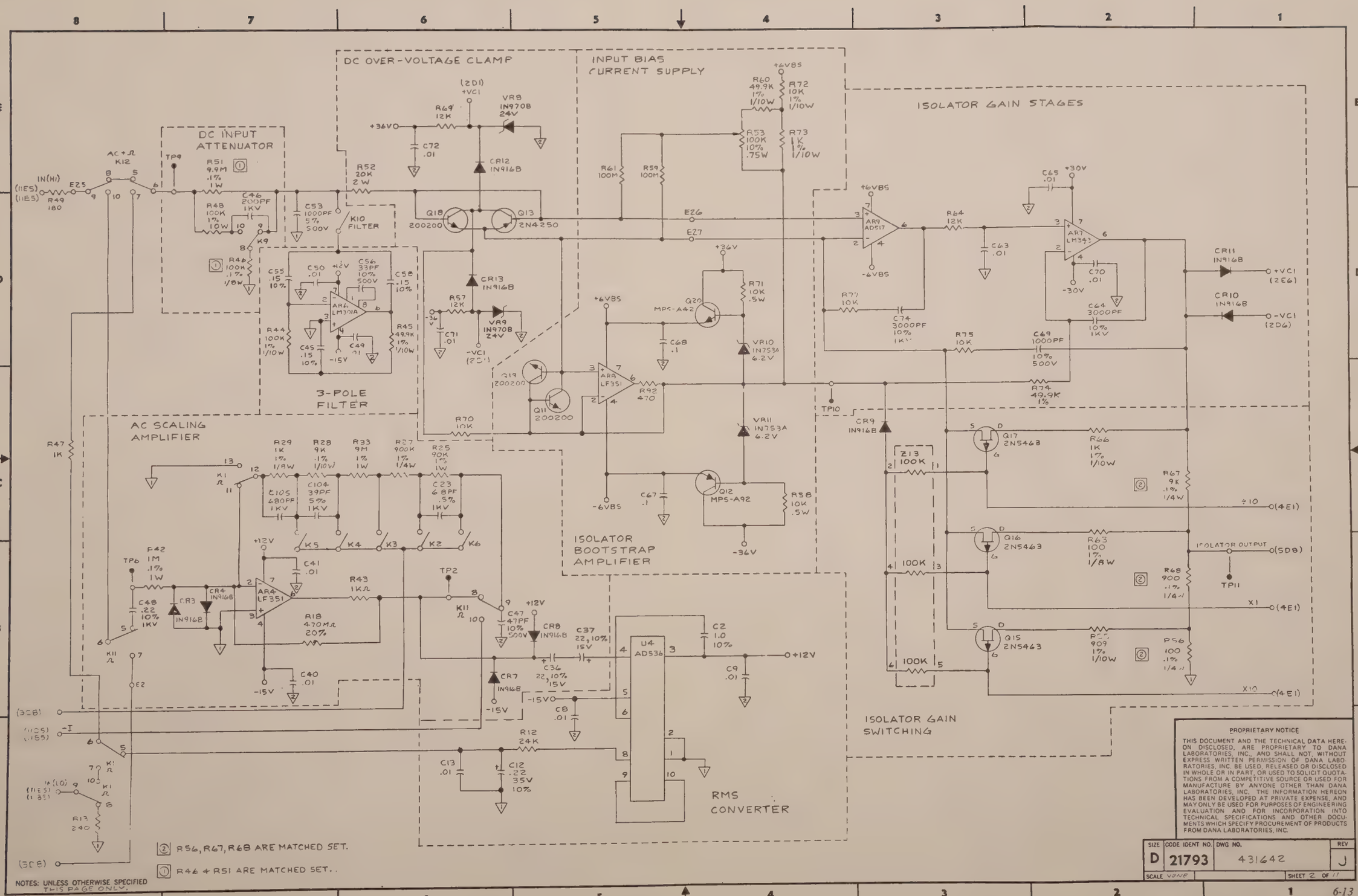
| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| AR4 | 230462 | IC | OP AMP | | | LF351N | 27014 | LF351N |
| AR6 | 230110 | IC | OP AMP | | | | 27014 | LM301A |
| AR7 | 230415 | IC | HI VOLTAGE OP AMP | | | | 27014 | LM343H |
| AR8 | 230462 | IC | OP AMP | | | LF351N | 27014 | LF351N |
| AR9 | 230470 | IC | OP AMP | | | AD517KH | 24355 | AD517KH |
| C2 | 120055 | CAP | MYLAR | 1 MFD | 100 V | 10% | 27556 | XA2B105K |
| C6 | 100043 | CAP | CERAM | .003 MFD | 1000 V | 10% | 71590 | DD302 |
| C8 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C9 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C12 | 110016 | CAP | TANTA | .22 MFD | 35 V | 10% | 05397 | T310A224K035AS |
| C13 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C23 | 100085 | CAP | CERAM | 6.8 PFD | 1000 V | 5% | 56289 | C030B102E6R8D |
| C36 | 110141 | CAP | TANTA | 22 MFD | 15 V | 20% | 05397 | T368B226M015AS |
| C37 | 110141 | CAP | TANTA | 22 MFD | 15 V | 20% | 05397 | T368B226M015AS |
| C40 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C41 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C45 | 120351 | CAP | FILM | .15 µF | 50 V | 10% | 55112 | 170-.15-K-160-DB |
| C46 | 100040 | CAP | CERAM | 200 PFD | 1000 V | 20% | 56289 | C023B102E201M |
| C47 | 101182 | CAP | CERAM | 47 PFD | 500 V | 10% | 71471 | TCD-DI-2(N750) |
| C48 | 120280 | CAP | MYLAR | .22 MFD | 1000 V | 10% | 27556 | ZA2J224K |
| C49 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C50 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C53 | 120004 | CAP | POLY | .001 MFD | 500 V | 5% | 08257 | KSO Series |
| C55 | 120351 | CAP | FILM | .15 µF | 50 V | 10% | 55112 | 170-.15-K-160-DB |
| C58 | 120351 | CAP | FILM | .15 µF | 50 V | 10% | 55112 | 170-.15-K-160-DB |
| C63 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C64 | 100043 | CAP | CERAM | .003 PFD | 1000 V | 10% | 71590 | DD302 |
| C65 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C67 | 100027 | CAP | CERAM | .1 MFD | 100 V | 20% | 72982 | 845-000-X5V01042 |
| C68 | 100027 | CAP | CERAM | .1 MFD | 100 V | 20% | 72982 | 845-000-X5V01042 |
| C69 | 101174 | CAP | CERAM | .001 MFD | 500 V | 10% | 04222 | SCD-DI-2X5F-1000 |
| C70 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C71 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C72 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C74 | 100043 | CAP | CERAM | .003 PFD | 1000 V | 10% | 71590 | DD302 |
| C104 | 100061 | CAP | CERAM | 39 PFD | 1000 V | 5% | 56289 | C030B102G390J |
| C105 | 100126 | CAP | CERAM | 680 PFD | 1 KV | 20% | 56289 | C023B102E681M |
| CR3 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR4 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR7 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR8 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR9 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR10 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR11 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR12 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR13 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| J2 | 600821 | CONN | | 6 P | | | 27264 | 09-03-1062 |
| J201 | 600957 | RECEPT | | 24 POS | | | 00779 | 552791-1 |
| K1 | 310146 | RELAY | CRADLE | 4 FORM C | | | 26806 | AZ421-08-204 |
| K2 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K3 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K4 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K5 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K6 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K7 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K8 | 310145 | RELAY | REED | 1 FORM A | | | 71707 | CR-4573 |
| K9 | 310147 | RELAY | REED | 2 FORM C | | | 26806 | AZ420-08-205 |
| K10 | 310144 | RELAY | REED | 1 FORM A | | | 21317 | 1A12R960DIAA |
| K11 | 310147 | RELAY | CRADLE | 2 FORM C | | | 26806 | AZ420-08-205 |
| K12 | 310147 | RELAY | CRADLE | 2 FORM C | | | 26806 | AZ420-08-205 |



| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|---|
| Q11 | 200200 | TRANS | NPN | | | | | 21793 | 200200 |
| Q12 | 200245 | TRANS | PNP | HIGH VOLTAGE | | | | 04713 | MPS-A92 |
| Q13 | 200068 | TRANS | PNP | | | | | 80131 | 2N4250 |
| Q15 | 200266 | TRANS | FET | P-CHANNEL | | 2N5463 | | 04713 | 2N5463 |
| Q16 | 200266 | TRANS | FET | P-CHANNEL | | 2N5463 | | 04713 | 2N5463 |
| Q17 | 200266 | TRANS | FET | P-CHANNEL | | 2N5463 | | 04713 | 2N5463 |
| Q18 | 200200 | TRANS | NPN | | | | | 21793 | 200200 |
| Q19 | 200200 | TRANS | NPN | | | | | 21793 | 200200 |
| Q20 | 200233 | TRANS | SILICO | NPN | | | | 04713 | MPS-A42 |
| R12 | 000243 | RES | CARBON | 24 K | | 5% 1/4W | | 81349 | RC07GF243J |
| R13 | 000241 | RES | CARBON | 240 OHM | | 5% 1/4W | | 81349 | RC07GF241J |
| R18 | 000477 | RES | CARBON | 470 M | | 20% 1/4W | | 01121 | CB4772 |
| R25 | 012061 | RES, METAL FILM | | 90 K OHM | | 1% 1.0W | | 03888 | PME70T-9 |
| R27 | 012058 | RES, METAL FILM | | 900 K OHM | | 1% .25W | | 03888 | PME60T-9 |
| R28 | 010749 | RES | METAL | 9 K | | .1% 1/10W | | 81349 | RN55E9001B |
| R29 | 012057 | RES, METAL FILM | | 1 K OHM | | 1% .25W | | 03888 | PME60T-9 |
| R33 | 012062 | RES, METAL FILM | | 9 M OHM | | 1% 1.0W | | 03888 | PME70T-9 |
| R42 | 010338 | RES | METAL | 1 M | | .1% 1W | | 03888 | PME75 |
| R43 | 000102 | RES | CARBON | 1 K | | 5% 1/4W | | 81349 | RC07GF102J |
| R44 | 010536 | RES | METAL | 100 K | | 1% 1/10W | | 81349 | RN55C1003F |
| R45 | 010621 | RES | METAL | 49.9 K | | 1% 1/10W | | 81349 | RN55C4992F |
| R46 | 012065 | RES | SET | 9.9M/100 K | | 0.1% | | 03888 | A3DR18 |
| R47 | 000102 | RES | CARBON | 1 K | | 5% 1/4W | | 81349 | RC07GF102J |
| R48 | 030015 | RES | WW | 100 K | | 1% 10W | | 21551 | M-100 |
| R49 | 000181 | RES | CARBON | 180 OHM | | 5% 1/4W | | 81349 | RC07GF181J |
| R51 | 012065 | RES | SET | 9.9M/100 K | MF | 0.1% | | 03888 | A3DR18 |
| R52 | 001873 | RES | CARBON | 20 K | | 5% 2W | | 01121 | See Description |
| R53 | 040235 | POT | CERMET | 100 K | | 10% 3/4W | | 73138 | 89PR100K |
| R55 | 010686 | RES | METAL | 909 OHM | | 1% 1/10W | | 81349 | RN55C9090F |
| R56 | 012063 | RES | SET | 100/900/9 K | MF | 0.1% | | 03888 | A3DR17 |
| R57 | 000123 | RES | CARBON | 12 K | | 5% 1/4W | | 81349 | RC07GF123J |
| R58 | 001676 | RES | CARBON | 10 K | | 5% 1/2W | | 81349 | RC20GF103J |
| R59 | 000107 | RES | CARBON | 100 M | | 5% 1/4W | | 81349 | RC07GF107J |
| R60 | 010621 | RES | METAL | 49.9 K | | 1% 1/10W | | 81349 | RN55C4992F |
| R61 | 000107 | RES | CARBON | 100 M | | 5% 1/4W | | 81349 | RC07GF107J |
| R63 | 010137 | RES | METAL | 100 OHM | T-0 | 1% 1/8W | | 81349 | RN60D1000F |
| R64 | 000123 | RES | CARBON | 12 K | | 5% 1/4W | | 81349 | RC07GF123J |
| R66 | 010704 | RES | METAL | 1 K | | 1% 1/10W | | 81349 | RN55D1001F |
| R67 | 012063 | RES | SET | 100/900/9 K | MF | 0.1% | | 03888 | A3DR17 |
| R68 | 012063 | RES | SET | 100/900/9 K | MF | 0.1% | | 03888 | A3DR17 |
| R69 | 000123 | RES | CARBON | 12 K | | 5% 1/4W | | 81349 | RC07GF123J |
| R70 | 000103 | RES | CARBON | 10 K | | 5% 1/4W | | 81349 | RC07GF103J |
| R71 | 001676 | RES | CARBON | 10 K | | 5% 1/2W | | 81349 | RC20GF103J |
| R72 | 010529 | RES | METAL | 10 K | | 1% 1/10W | | 81349 | RN55C1002F |
| R73 | 010704 | RES | METAL | 1 K | | 1% 1/10W | | 81349 | RN55D1001F |
| R74 | 010621 | RES | METAL | 49.9 K | | 1% 1/10W | | 81349 | RN55C4992F |
| R75 | 000103 | RES | CARBON | 10 K | | 5% 1/4W | | 81349 | RC07GF103J |
| R77 | 000103 | RES | CARBON | 10 K | | 5% 1/4W | | 81349 | RC07GF103J |
| R92 | 000471 | RES | CARBON | 470 OHM | | 5% 1/4W | | 81349 | RC07GF471J |
| U4 | 230469 | IC | RMS TO DC CONVERTER AD536AJD | | | | | 24355 | AD536AJD |
| VR8 | 220060 | DIODE | ZENER | | | | | 21793 | 220060 |
| VR9 | 220060 | DIODE | ZENER | | | | | 21793 | 220060 |
| VR10 | 220040 | DIODE | ZENER | | | | | 81349 | 1N753A |
| VR11 | 220040 | DIODE | ZENER | | | | | 81349 | 1N753A |
| Z13 | 080039 | RES NW CERMET | | 100 K | 6P,3R | 2% .9W | | 11236 | 750-63-R100KΩ |



*6-11/6-12 Blank*





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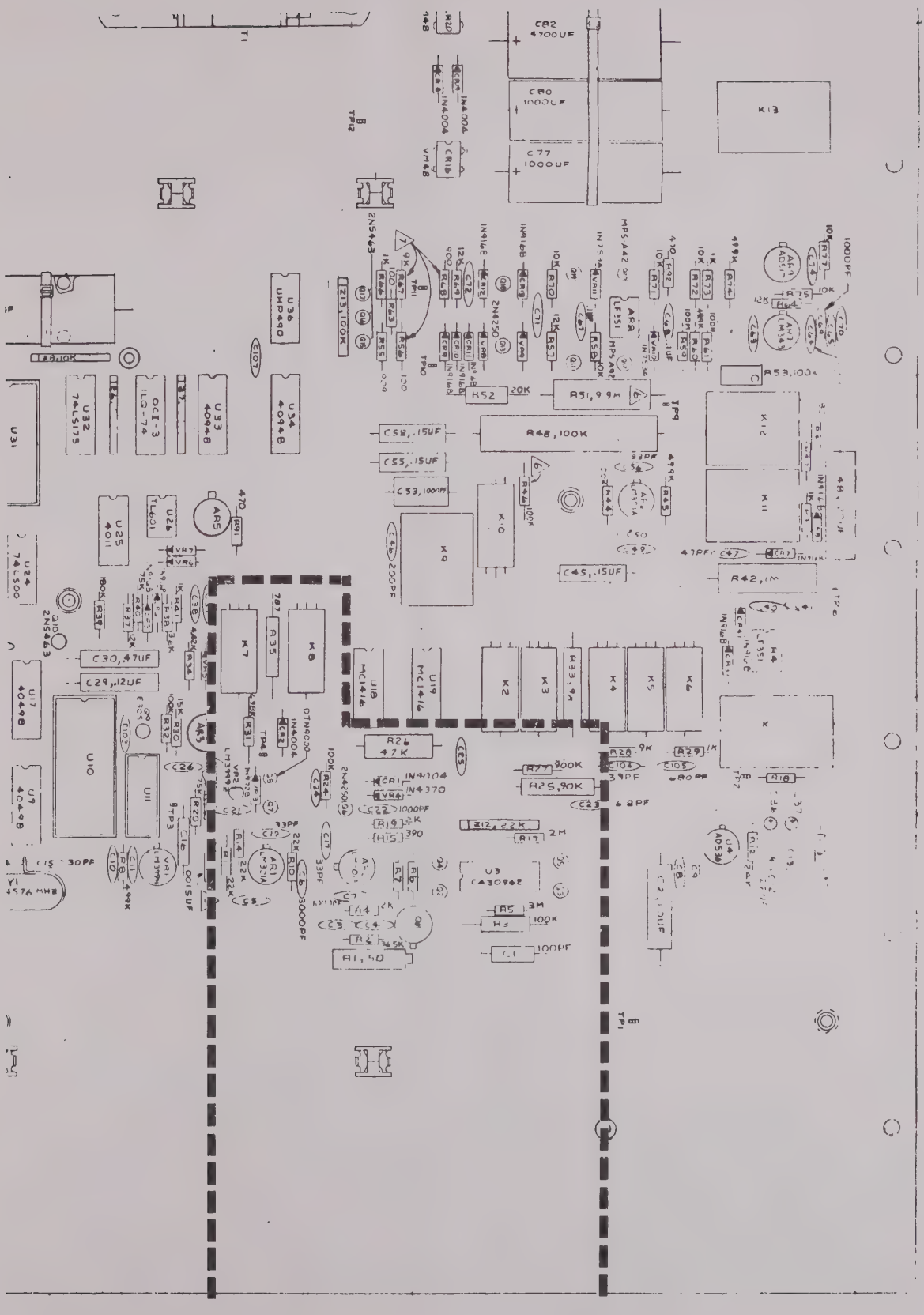
| SIZE | CODE IDENT NO. | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 431642 | J |
| SCALE VONR | | | SHEET 2 OF 11 |

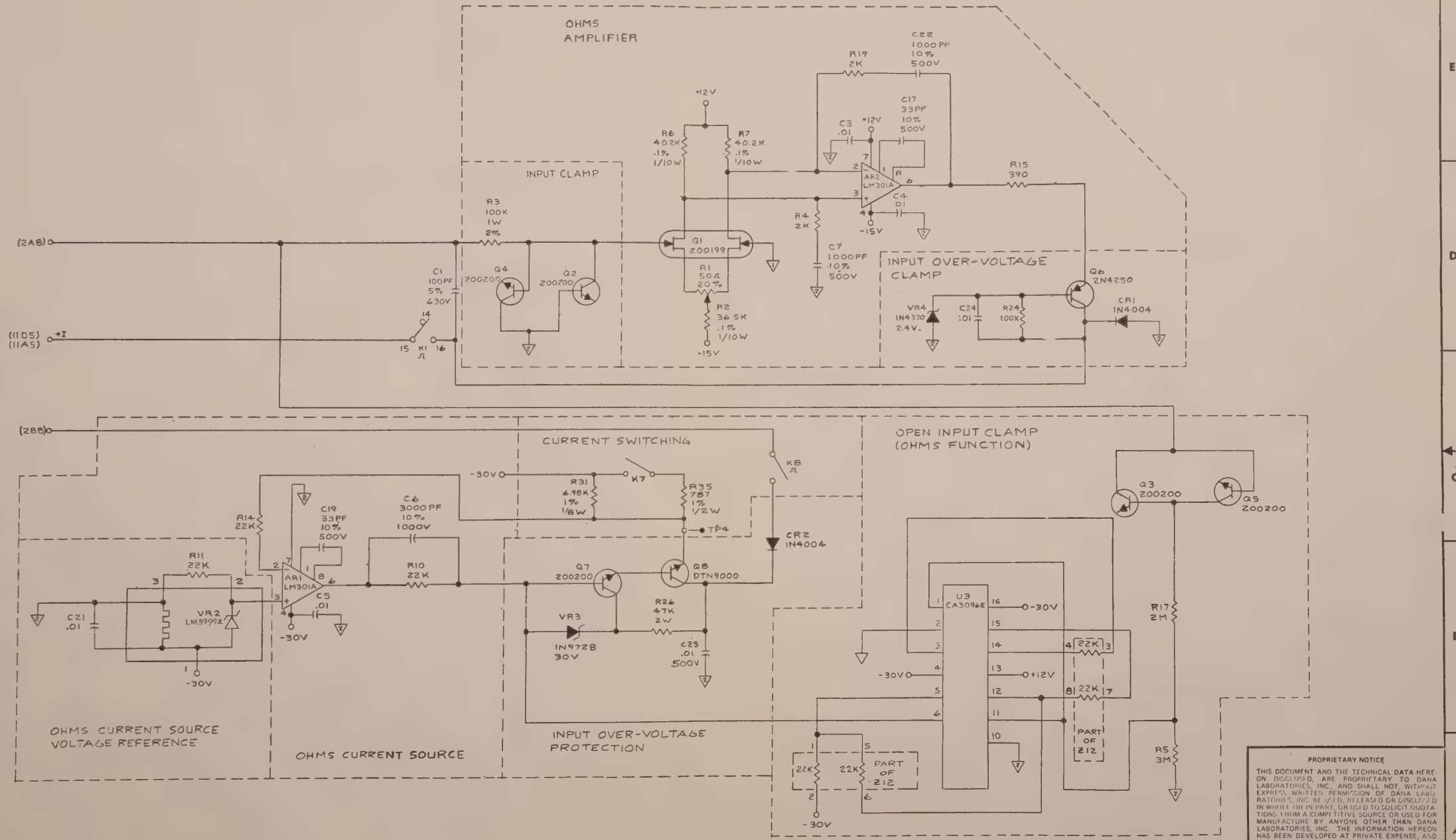
401642 – Assy., PCB, MOTHERBOARD (OHMS)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| AR1 | 230110 | IC | OP AMP | | | | 27014 | LM301A |
| AR2 | 230110 | IC | OP AMP | | | | 27014 | LM301A |
| C1 | 120034 | CAP | POLY | 100 PFD | 630 V | 5% | 08257 | KSO Series |
| C3 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C4 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C5 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C7 | 101174 | CAP | CERAM | .001 MFD | 500 V | 10% | 04222 | SCD-DI-2X5F-100 |
| C17 | 100012 | CAP | CERAM | 33 PFD | 500 V | 10% | 71471 | TCD-DI-1(N750) |
| C19 | 100012 | CAP | CERAM | 33 PFD | 500 V | 10% | 71471 | TCD-DI-1(N750) |
| C21 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C22 | 101174 | CAP | CERAM | .001 MFD | 500 V | 10% | 04222 | SCD-DI-2X5F-100 |
| C24 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C25 | 100063 | CAP | CERAM | .01 MFD | 500 V | 20% | 56289 | C023B501E103M |
| C56 | 100012 | CAP | CERAM | 33 PFD | 500 V | 10% | 71471 | TCD-DI-1(N750) |
| CR1 | 210004 | DIODE | SILICO | | | | 81349 | 1N4004 |
| CR2 | 210004 | DIODE | SILICO | | | | 81349 | 1N4004 |
| CR5 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR6 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| Q1 | 200199 | TRANS | FET | | | | 27014 | FM1302 |
| Q2 | 200200 | TRANS | NPN | | | | 21793 | 200200 |
| Q3 | 200200 | TRANS | NPN | | | | 21793 | 200200 |
| Q4 | 200200 | TRANS | NPN | | | | 21793 | 200200 |
| Q5 | 200200 | TRANS | NPN | | | | 21793 | 200200 |
| Q6 | 200068 | TRANS | PNP | | | | 80131 | 2N4250 |
| Q7 | 200200 | TRANS | NPN | | | | 21793 | 200200 |
| Q8 | 200267 | TRANS | NPN | | 400 V | | 50857 | DTN9000 |
| R1 | 040225 | POT | CERMET | 50 OHM | | 20% | 73138 | 89PR50 |
| R2 | 010790 | RES | METAL | 36.5 K | | 1% 1/10W | 81349 | RN55E3652F |
| R3 | 010838 | RES | CARBON | 100 K | | 2% 1W | 91637 | SBF100K2% |
| R4 | 000202 | RES | CARBON | 2 K | | 5% 1/4W | 81349 | RC07GF202J |
| R5 | 000305 | RES | CARBON | 3 M | | 5% 1/4W | 81349 | RC07GF305J |
| R6 | 012023 | RES | METAL | 40.2 K | | .1% 1/10W | 81349 | RN55E4022B |
| R7 | 012023 | RES | METAL | 40.2 K | | .1% 1/10W | 81349 | RN55E4022B |
| R10 | 000223 | RES | CARBON | 22 K | | 5% 1/4W | 81349 | RC07GF223J |
| R11 | 000223 | RES | CARBON | 22 K | | 5% 1/4W | 81349 | RC07GF223J |
| R14 | 000223 | RES | CARBON | 22 K | | 5% 1/4W | 81349 | RC07GF223J |
| R15 | 000391 | RES | CARBON | 390 OHM | | 5% 1/4W | 81349 | RC07GF391J |

401642 – Assy., PCB, MOTHERBOARD (OHMS) continued

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| R17 | 000205 | RES | CARBON | 2 M | | 5% 1/4W | 81349 | RC07GF205J |
| R19 | 000202 | RES | CARBON | 2 K | | 5% 1/4W | 81349 | RC07GF202J |
| R24 | 000104 | RES | CARBON | 100 K | | 5% 1/4W | 81349 | RC07GF104J |
| R26 | 001816 | RES | CARBON | 47 K | | 5% 2W | 01121 | See Description |
| R31 | 012060 | RES, METAL FILM | | 6.98 K OHM | | 1% .12W | 03888 | PME55T-9 |
| R35 | 012059 | RES, METAL FILM | | 787 OHM | | 1% .50W | 03888 | PME65T-9 |
| U3 | 230461 | IC | TRANSISTOR ARRAY | | | | 18722 | CA3096E |
| VR2 | 230454 | IC | +7V REFERENCE | | | | 27014 | LM3999Z |
| VR3 | 220088 | DIODE | ZENER | 30 V | | | 04713 | 1N972B |
| VR4 | 220020 | DIODE | SILICO, ZENER | | | | 81349 | 1N4370 |
| Z12 | 080040 | RES NW | CERMET | 22 K | 8P,4R | 2% 1.1W | 11236 | 750-83-R22KΩ |




OHMS AMPLIFIER
INPUT CLAMP
INPUT OVER-VOLTAGE CLAMP
CURRENT SWITCHING
OPEN INPUT CLAMP (OHMS FUNCTION)
OHMS CURRENT SOURCE VOLTAGE REFERENCE
OHMS CURRENT SOURCE
INPUT OVER-VOLTAGE PROTECTION
(2A8)
(2B8)
(11D5) (11A5) +I
+12V
-15V
-30V
0-30V
0+12V
R1 50Ω 20%
R2 36.5K .1% 1/10W
R3 100K 1W 2%
R4 2K
R5 3M
R6 40.2K .1% 1/10W
R7 40.2K .1% 1/10W
R10 22K
R11 22K
R14 22K
R15 390
R17 2M
R19 2K
R24 100K
R26 47K 2W
R31 6.98K 1% 1/8W
R35 787 1% 1/2W
C1 100PF 5% 630V
C3 .01
C4 .01
C5 .01
C6 3000PF 10% 1000V
C7 1000PF 10% 500V
C17 33PF 10% 500V
C19 33PF 10% 500V
C21 .01
C22 1000PF 10% 500V
C24 .01
C25 .01 500V
Q1 200199
Q2 200200
Q3 200200
Q4 200200
Q5 200200
Q6 2N4250
Q7 200200
Q8 DTN9000
AR1 LM301A
AR2 LM301A
U3 CA3096E
VR2 LM399Z
VR3 IN972B 30V
VR4 IN4370 2.4V.
CR1 IN4004
CR2 IN4004
K1
K7
K8
TP4
PART OF Z12
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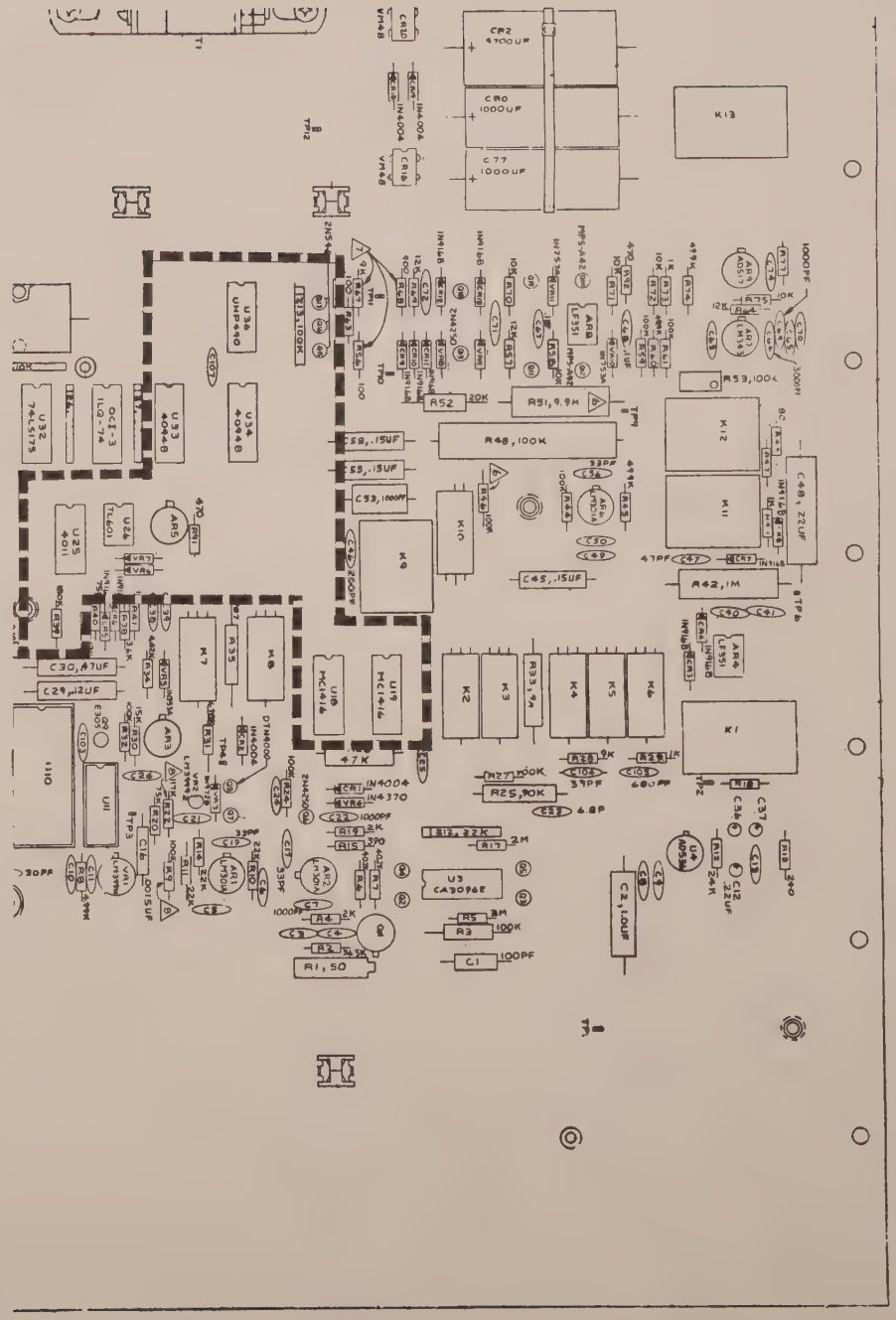
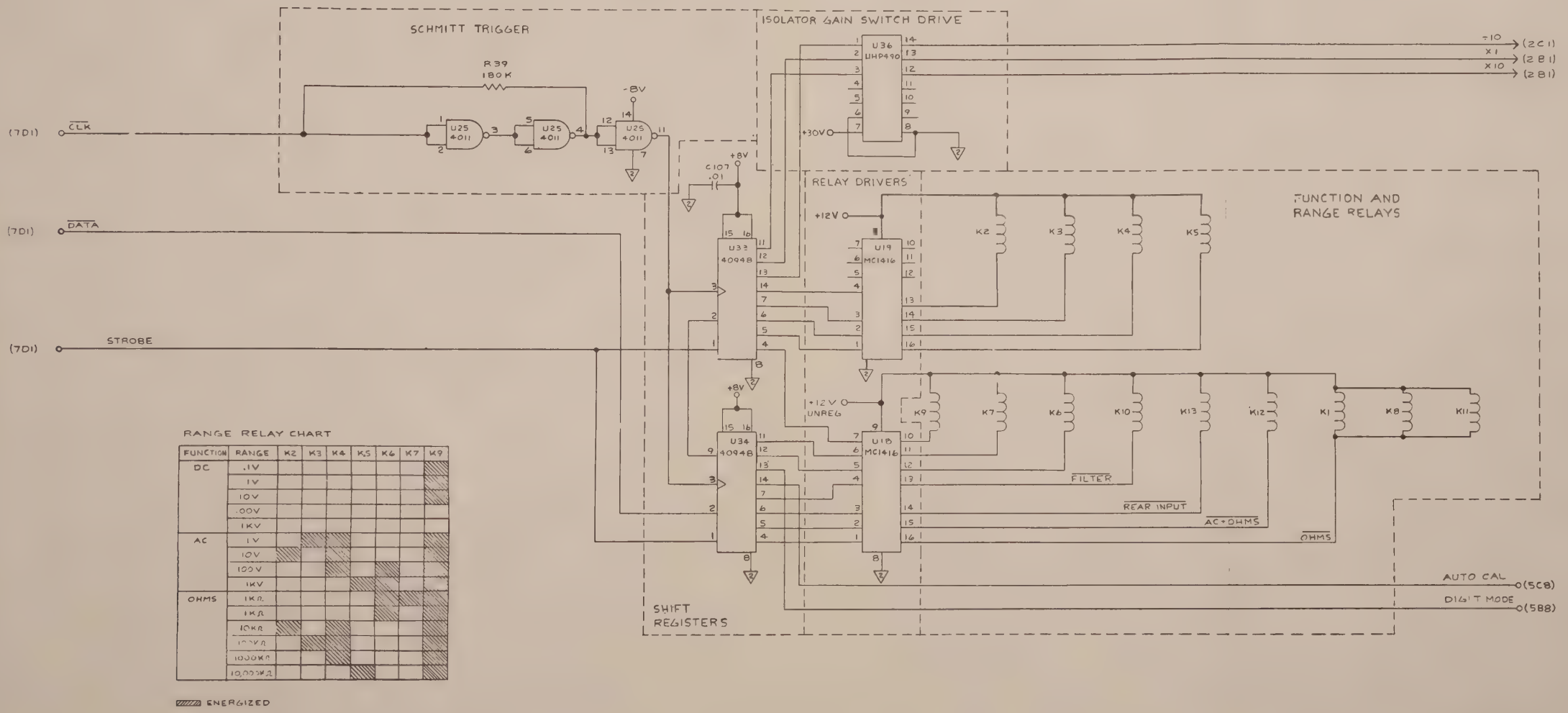
SIZE D
CODE IDENT NO. 21793
DWG NO. 431642
REV J
SCALE NONE
SHEET 3 OF 11
NOTES: UNLESS OTHERWISE SPECIFIED
6-17

401642 – Assy., PCB, MOTHERBOARD (RELAY DRIVE)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| C107 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| R39 | 000184 | RES | CARBON | 180 K | | 5% 1/4W | 81349 | RC07GF184J |
| U18 | 230464 | IC | RELAY DRIVER | | MC1416P | | 04713 | MC1416P |
| U19 | 230464 | IC | RELAY DRIVER | | MC1416P | | 04713 | MC1416P |
| U25 | 230466 | IC | CMOS QUAD NAND GATE | | | | 18722 | CD4011AE |
| U33 | 230404 | IC | | | | | 86884 | CD4094BE |
| U34 | 230404 | IC | | | | | 86884 | CD4094BE |
| U36 | 230471 | IC | 5 CHANNEL DRIVER | | | | 56289 | VHP-490 |






RANGE RELAY CHART

| FUNCTION | RANGE | K2 | K3 | K4 | K5 | K6 | K7 | K9 |
|---|---|---|---|---|---|---|---|---|
| DC | .1V | | | | | | | ▨ |
| | 1V | | | | | | | |
| | 10V | | | | | | | ▨ |
| | 100V | | | | | | | |
| | 1KV | | | | | | | |
| AC | 1V | | ▨ | ▨ | | | | ▨ |
| | 10V | ▨ | | ▨ | | | | ▨ |
| | 100V | | | ▨ | | ▨ | | ▨ |
| | 1KV | | | | ▨ | ▨ | | ▨ |
| OHMS | 1KΩ | | | | | ▨ | ▨ | ▨ |
| | 10KΩ | ▨ | | ▨ | | | | ▨ |
| | 100KΩ | | ▨ | ▨ | | | | ▨ |
| | 1000KΩ | | | ▨ | | | | ▨ |
| | 10,000KΩ | | | | ▨ | | | ▨ |

▨ ENERGIZED

NOTES: UNLESS OTHERWISE SPECIFIED

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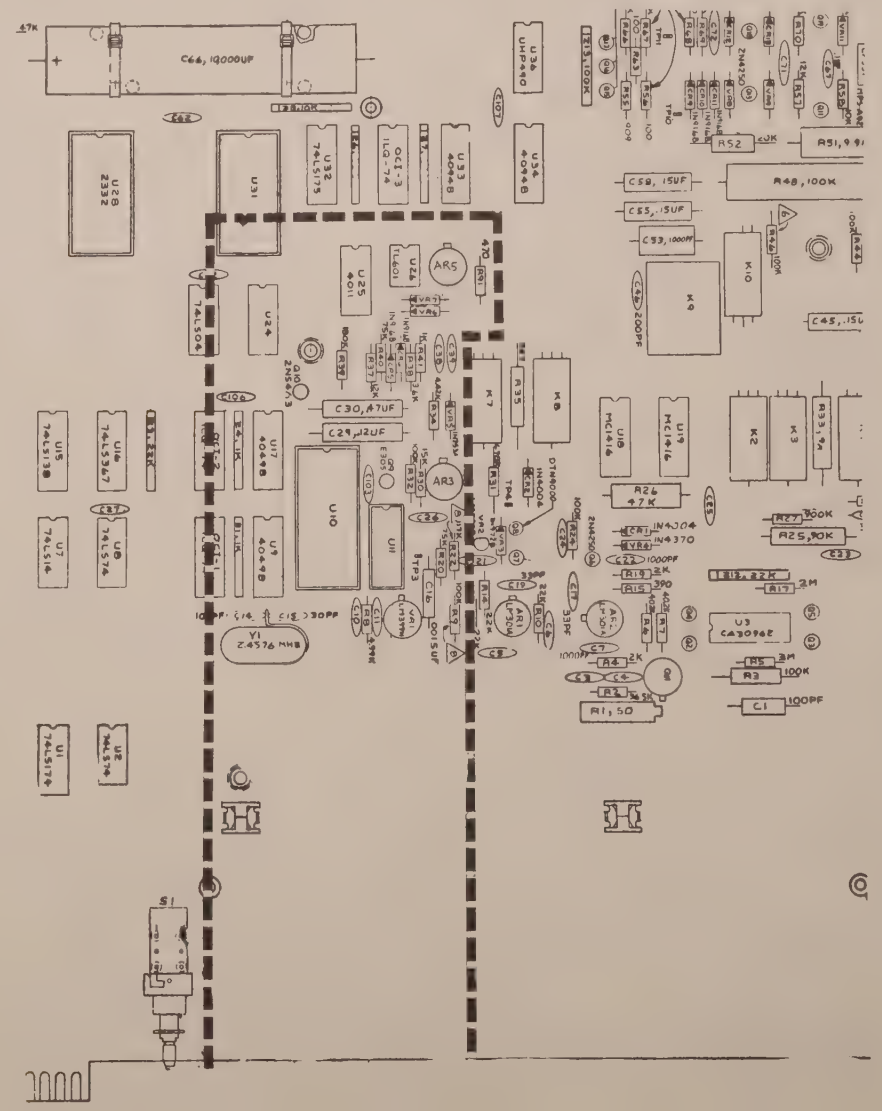
| SIZE | CODE IDENT NO. | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 431642 | J |
| SCALE NONE | | SHEET 4 OF 11 | |

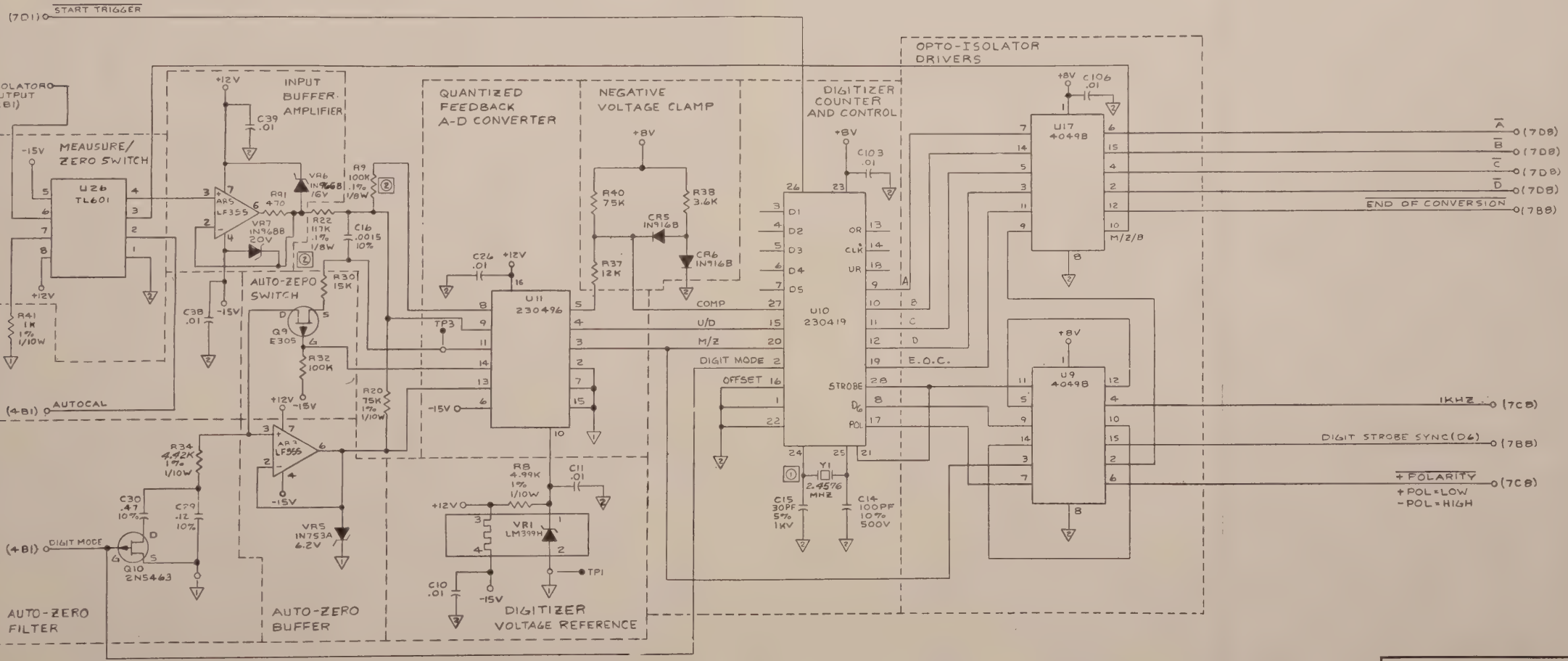
401642 – Assy., PCB, MOTHERBOARD (A/D CONVERTER)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| AR3 | 230331 | IC | OP AMP | | | LF355H | 27014 | LF355H |
| AR5 | 230331 | IC | OP AMP | | | LF355H | 27014 | LF355H |
| C10 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C11 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C14 | 101145 | CAP | CERAM | 100 PFD | 500 V | 10% | 04222 | TCD-DI-1N5600-100 |
| C15 | 100099 | CAP | CERAM | 30 PFD | 1000 V | 5% | 56289 | C030B102F300J |
| C16 | 121473 | CAP | MYLAR | .0015 MFD | 100 V | 10% | 09023 | WMF1S47 |
| C26 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C29 | 120352 | CAP | MYLAR | .12 µF | 100 V | 10% | 09023 | WMF1P12 |
| C30 | 120026 | CAP | MYLAR | .47 MFD | 100 V | 10% | 27556 | SAZB474K |
| C38 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C39 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C103 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C106 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| Q9 | 200230 | TRANS | FET | N-CHAN, SIL JUNCTION | | | | E305 |
| Q10 | 200266 | TRANS | FET | P-CHANNEL | | 2N5463 | 04713 | 2N5463 |
| R8 | 010829 | RES | METAL | 4.99 K | | 1% 1/10W | 81349 | RN55C4991F |
| R9 | 012064 | RES | SET | 100K/117 K | MF | 0.1% | 03888 | A3DR16 |
| R20 | 010679 | RES | METAL | 75 K | | 1% 1/10W | 81349 | RN55C7502F |
| R22 | 012064 | RES | SET | 100K/117 K | MF | 0.1% | 03888 | A3DR16 |
| R30 | 000153 | RES | CARBON | 15 K | | 5% 1/4W | 81349 | RC07GF153J |
| R32 | 000104 | RES | CARBON | 100 K | | 5% 1/4W | 81349 | RC07GF104J |
| R34 | 010723 | RES | METAL | 4.42 K | | 1% 1/10W | 81349 | RN55C4421F |
| R37 | 000123 | RES | CARBON | 12 K | | 5% 1/4W | 81349 | RC07GF123J |
| R38 | 000362 | RES | CARBON | 3.6 K | | 5% 1/4W | 81349 | RC07GF362J |
| R40 | 000753 | RES | CARBON | 75 K | | 5% 1/4W | 81349 | RC07GF753J |
| R41 | 010704 | RES | METAL | 1 K | | 1% 1/10W | 81349 | RN55D1001F |
| R91 | 000471 | RES | CARBON | 470 OHM | | 5% 1/4W | 81349 | RC07GF471J |
| U9 | 230460 | IC | HEX INVERTER | | | | 18722 | CD4049BE |
| U10 | 230419 | IC | CUSTOM SPEC. | | | | 04713 | 230419 |
| U11 | 230496 | IC | SELECTED LD120CJ | | | | 21793 | 230491 |
| U17 | 230460 | IC | HEX INVERTER | | | | 18722 | CD4049BE |
| U26 | 230468 | IC | ANALOG SWITCHES | | | | 01295 | TL601CP |
| VR1 | 230453 | IC | (+7V REFERENCE) | | | | 27014 | LM399H |
| VR5 | 220040 | DIODE | ZENER | | | | 81349 | 1N753A |
| VR6 | 220035 | DIODE | ZENER | 16 V | | 5% | 81349 | 1N966B |

401642 – Assy., PCB, MOTHERBOARD (A/D CONVERTER) continued

| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| VR7 | 220011 | DIODE SILICO, ZENER | 81349 | 1N968B |
| Y1 | 920846 | CRYSTAL 2.4576 MHz | | 2.4576 MHz |






R9 AND R22 IS MATCHED RESISTOR SET.

Y1 2.4576 MHZ FOR 60HZ.
2.048 MHZ FOR 50HZ.

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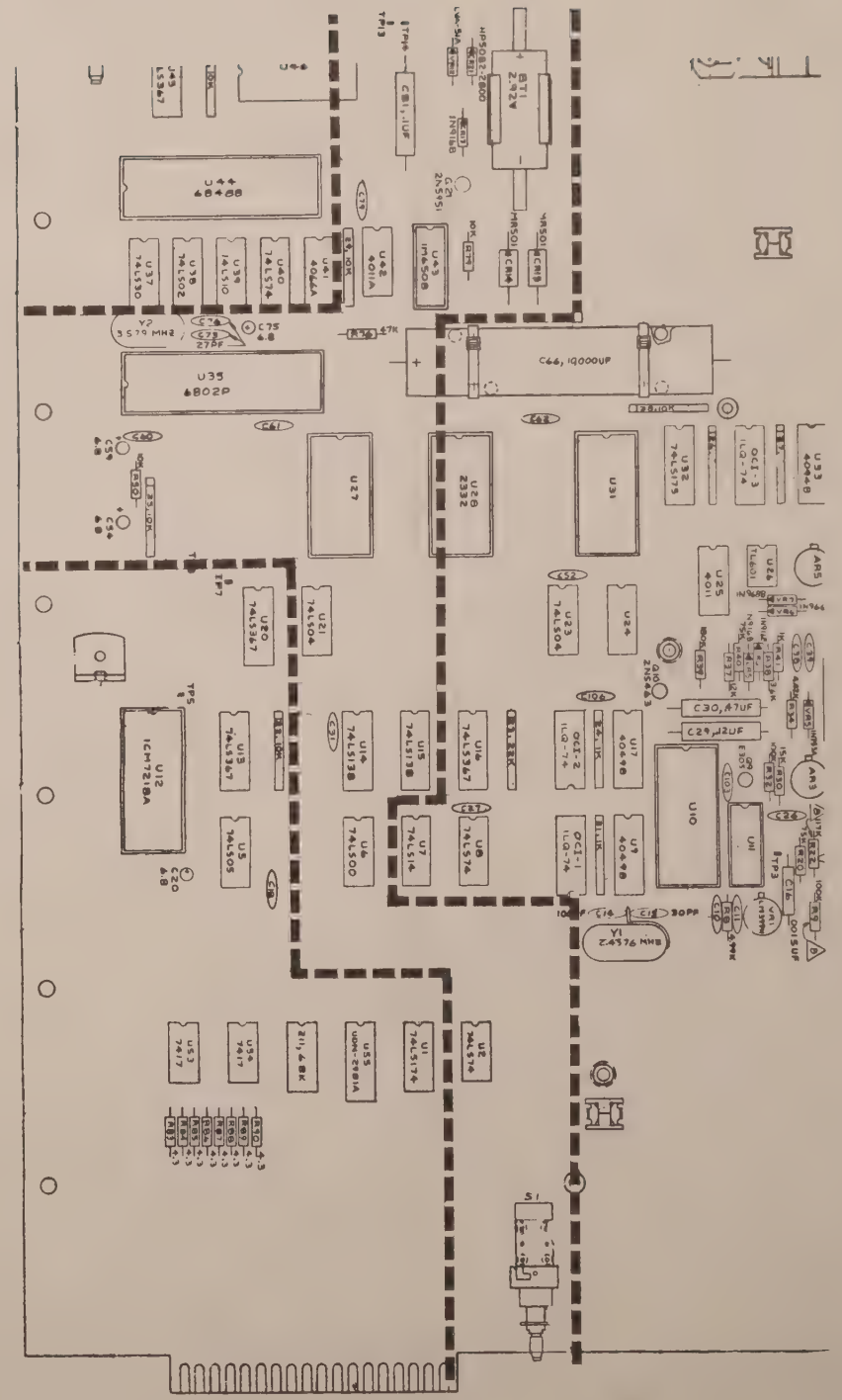
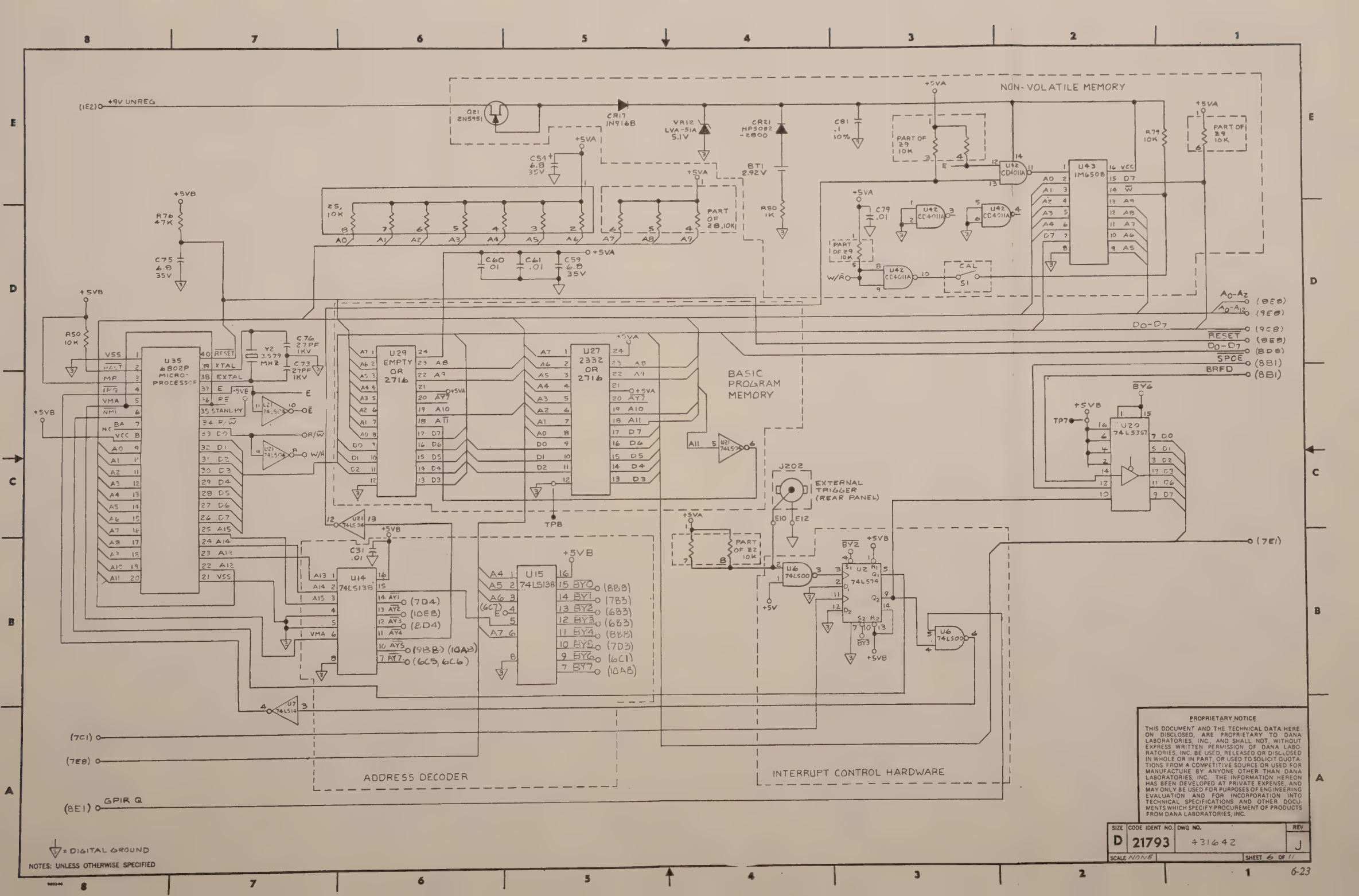
| SIZE | CODE IDENT NO | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 431642 | J |
| SCALE | | SHEET 5 OF 11 | |

401642 – Assy., PCB, MOTHERBOARD (μP CONTROL & NON-VOL)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| BT1 | 920847 | BATTERY | | 3 VOLT | Lithium Organic | | 90201 | L032S |
| C31 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C54 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C59 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C60 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C61 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C73 | 100016 | CAP | CERAM | 27 PFD | 1000 V | 10% | 71590 | DD270 |
| C75 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| C76 | 100016 | CAP | CERAM | 27 PFD | 1000 V | 10% | 71590 | DD270 |
| C79 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C81 | 120003 | CAP | MYLAR | .1 MFD | 100 V | | 09023 | WMF1P1 |
| CR17 | 211083 | DIODE | SILICO | | | 1N916B | 81349 | 1N916B |
| CR21 | 210015 | DIODE | | | | | 50434 | HP5082-2800 |
| Q21 | 200265 | TRANS | FET | | | 2N5951 | 01295 | 2N5951 |
| R50 | 000103 | RES | CARBON | 10 K | | 5% 1/4W | 81349 | RC07GF103J |
| R76 | 000473 | RES | CARBON | 47 K | | 5% 1/4W | 81349 | RC07GF473J |
| R79 | 000103 | RES | CARBON | 10 K | | 5% 1/4W | 81349 | RC07GF103J |
| R80 | 000102 | RES | CARBON | 1 K | | 5% 1/4W | 81349 | RC07GF102J |
| S1 | 600926 | SWITCH, SLIDE PUSHBUTTON, MOMENTARY, Single, 2 Pole | | | | | 71590 | PBI Series |
| U2 | 230194 | IC | 14 DIP, DUAL D FLIP-FLOP | | | | 01295 | SN74LS74N |
| U6 | 230193 | IC | 14 DIP, NAND GATE | | | | 01295 | SN74LS00N |
| U7 | 230336 | IC | | | | | 01295 | 74LS14 |
| U14 | 230368 | IC | | | | | 27014 | 74LS138 |
| U15 | 230368 | IC | | | | | 27014 | 74LS138 |
| U20 | 230330 | IC | | | | | 01295 | 74LS367 |
| U21 | 230234 | IC | 14 DIP, HEX INVERTER | | | | 01295 | SN74LS04N |
| U27 | 230481 | IC | MEMORY ROM | | | | 21793 | 230481 |
| U35 | 230369 | IC | | | | | 04713 | 6802-P |
| U42 | 230466 | IC | CMOS QUAD NAND GATE | | | | 18722 | CD4011AE |
| U43 | 230455 | IC | CMOS MEMORY | | | | 32293 | 1M6508 |
| VR12 | 220087 | DIODE | ZENER | 5.1 V | | | 07716 | LVA51A |
| Y2 | 920840 | CRYSTAL | | 3.579 MHz | | | | 1107863-1 |
| Z2 | 080020 | RES | CERMET | 10 K | Network 8P,7R | 2% | 11236 | 750-81-R10KΩ |
| Z5 | 080020 | RES | CERMET | 10 K | Network 8P,7R | 2% | 11236 | 750-81-R10KΩ |
| Z8 | 080020 | RES | CERMET | 10 K | Network 8P,7R | 2% | 11236 | 750-81-R10KΩ |
| Z9 | 080020 | RES | CERMET | 10 K | Network 8P,7R | 2% | 11236 | 750-81-R10KΩ |




NON-VOLATILE MEMORY
BASIC PROGRAM MEMORY
ADDRESS DECODER
INTERRUPT CONTROL HARDWARE
EXTERNAL TRIGGER (REAR PANEL)
U35 6802P MICRO-PROCESSOR
U29 EMPTY OR 2716
U27 2332 OR 2716
U43 IM6508
U22 74LS367
U14 74LS138
U15 74LS138
U2 74LS74
U6 74LS00
+9V UNREG
+5VA
+5VB
Y2 3.579 MHz
BT1 2.92V
CAL
S1
J202
TP7
TP8
GPIR Q
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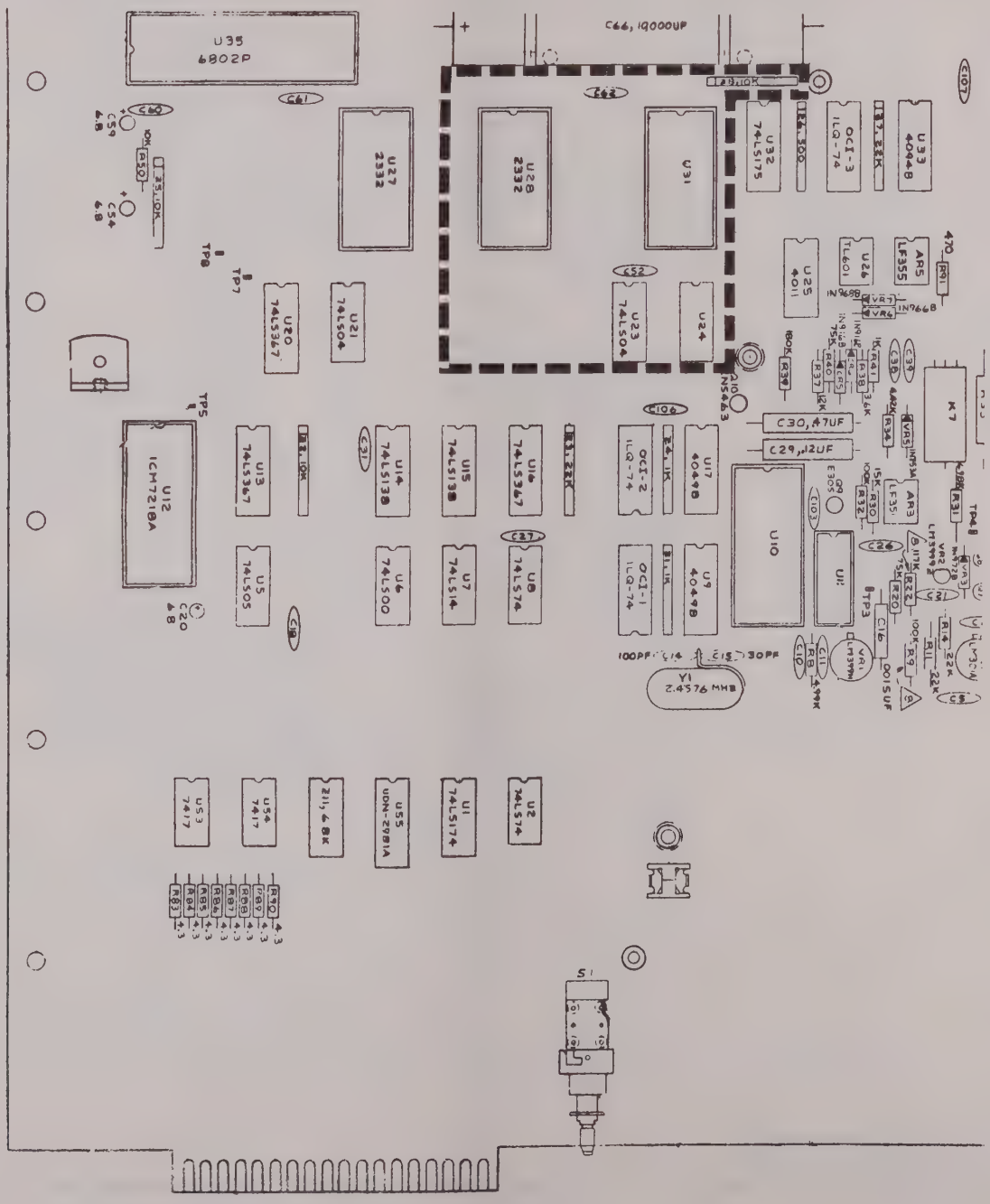
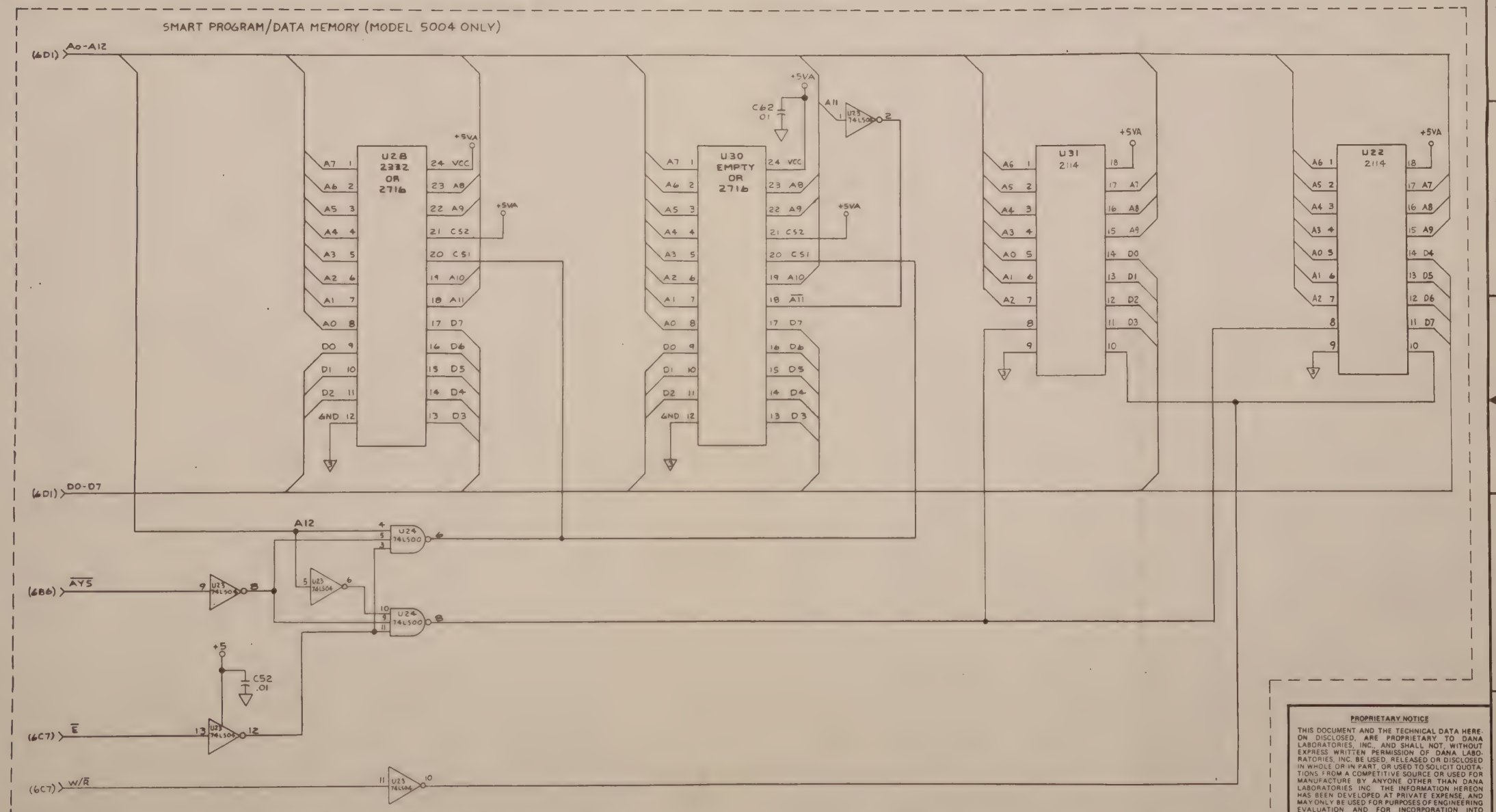
SIZE D
CODE IDENT NO. 21793
DWG NO. 431642
REV J
SCALE NONE
SHEET 6 OF 11
= DIGITAL GROUND
NOTES: UNLESS OTHERWISE SPECIFIED
6-23

| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| C62 | 100017 | CAP CERAM .01 MFD 100 V 20% | 56289 | C023B101F103M |
| U23 | 230234 | IC 14 DIP, HEX INVERTER | 01295 | SN74LS04N |
| U24 | 230193 | IC 14 DIP, NAND GATE | 01295 | SN74LS00N |
| U28* | 230495 | IC ROM CTED 4K x 8 | 21793 | 230495 |
| U31 | 230458 | IC STATIC RAM MEMORY CHIP | 50088 | MK4118-4 |

*The following two IC's may be used in place of U28 P/N 230495

| | | | | |
|---|---|---|---|---|
| U28 | 230500 | IC PROGRAMMED 2716 | 21793 | 230500 |
| U30 | 230502 | IC PROGRAMMED 2716 | 21793 | 230502 |



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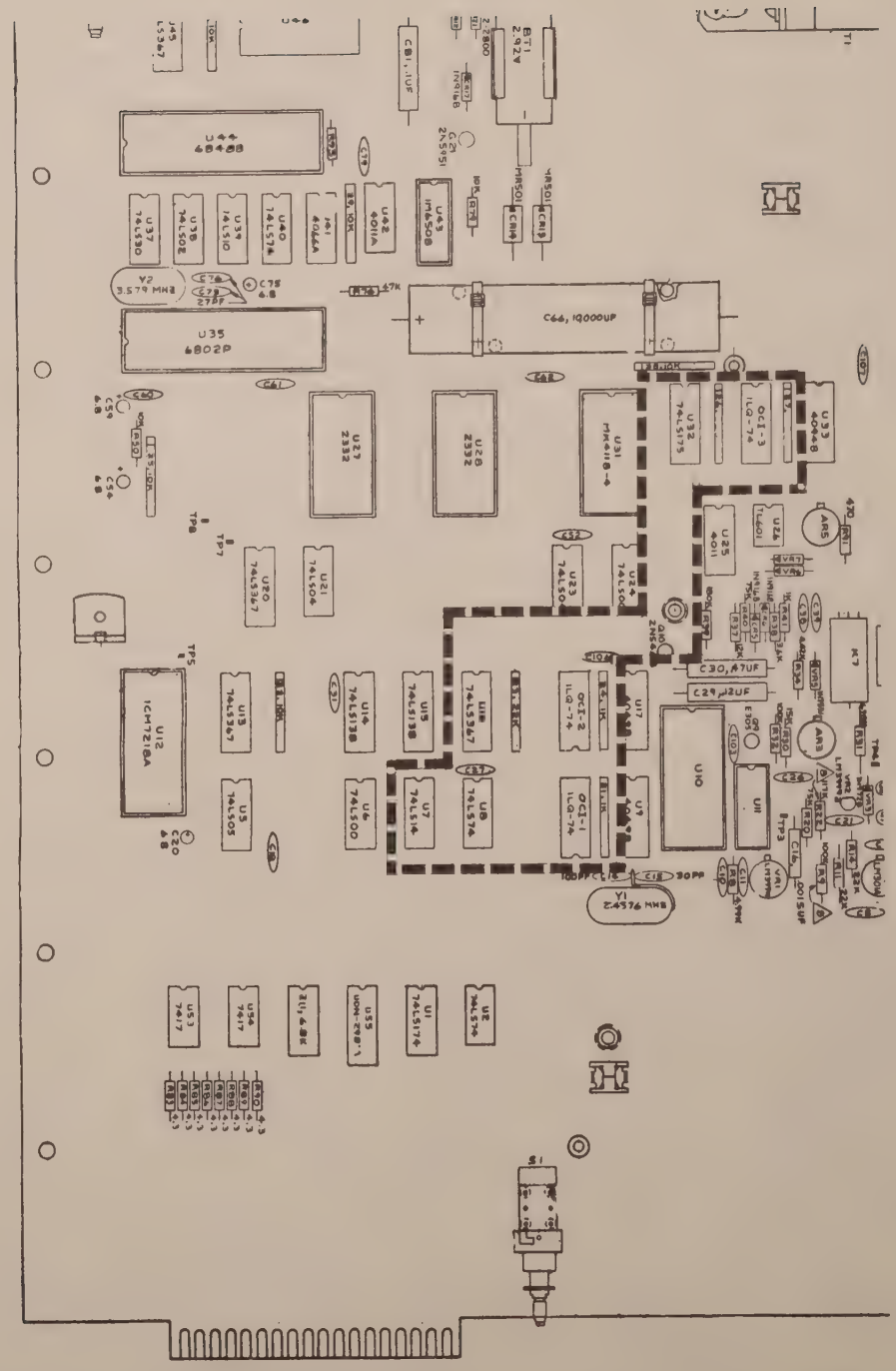
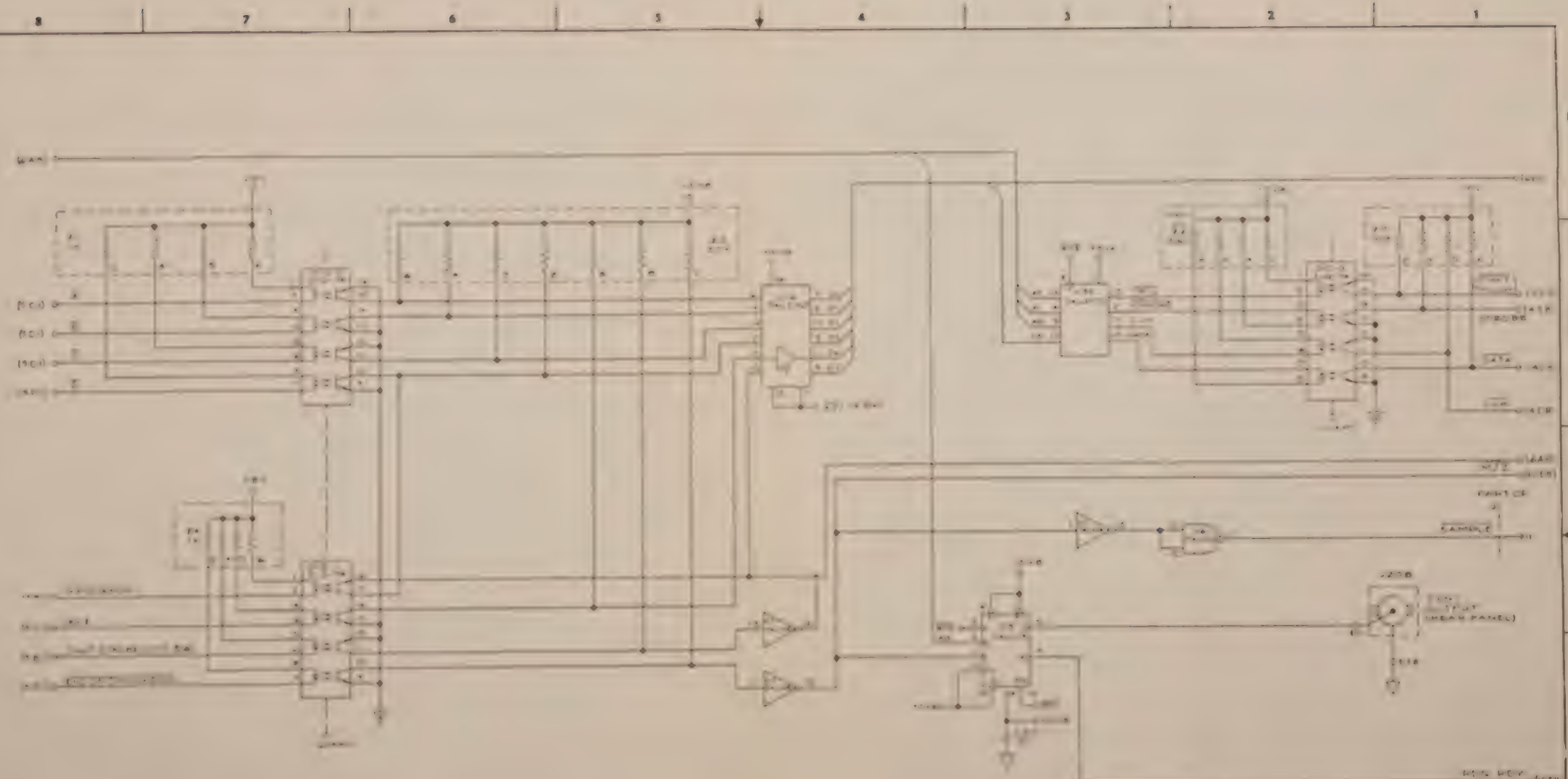
| SIZE | CODE IDENT NO. | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 431642 | J |
| SCALE NONE | | SHEET 9 OF 11 | |

NOTES: UNLESS OTHERWISE SPECIFIED

401642 – Assy., PCB, MOTHERBOARD (OCI 1, 2, 3)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| C27 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| OCI1 | 230456 | IC | QUAD OPTO-ISOLATOR | | | | 50579 | ISO-LITQ74 |
| OCI2 | 230456 | IC | QUAD OPTO-ISOLATOR | | | | 50579 | ISO-LITQ74 |
| OCI3 | 230456 | IC | QUAD OPTO-ISOLATOR | | | | 50579 | ISO-LITQ74 |
| U6 | 230193 | IC | 14 DIP, NAND GATE | | | | 01295 | SN74LS00N |
| U7 | 230336 | IC | | | | | 01295 | 74LS14 |
| U8 | 230194 | IC | 14 DIP, DUAL D FLIP-FLOP | | | | 01295 | SN74LS74N |
| U16 | 230330 | IC | | | | | 01295 | 74LS367 |
| U32 | 230356 | IC | | | | | 27014 | 74LS175 |
| Z1 | 080011 | RES | CERMET | 1 K | Network 8P,7R | 2% | 11236 | 750-81-R1KΩ |
| Z3 | 080030 | RES | CERMET | 22 K | Network 8P,7R | 2% | 11236 | 750-81-R22KΩ |
| Z4 | 080011 | RES | CERMET | 1 K | Network 8P,7R | 2% | 11236 | 750-81-R1KΩ |
| Z6 | 080001 | RES | CERMET | 330 OHM | Network 8P,7R | 2% | 11236 | 750-81-R330Ω |
| Z7 | 080020 | RES | CERMET | 10 K | Network 8P,7R | 2% | 11236 | 750-81-R10KΩ |





NOTES: UNLESS OTHERWISE SPECIFIED

| SIZE | DRAWING NO. | REV |
|---|---|---|
| D | 21793 | J |

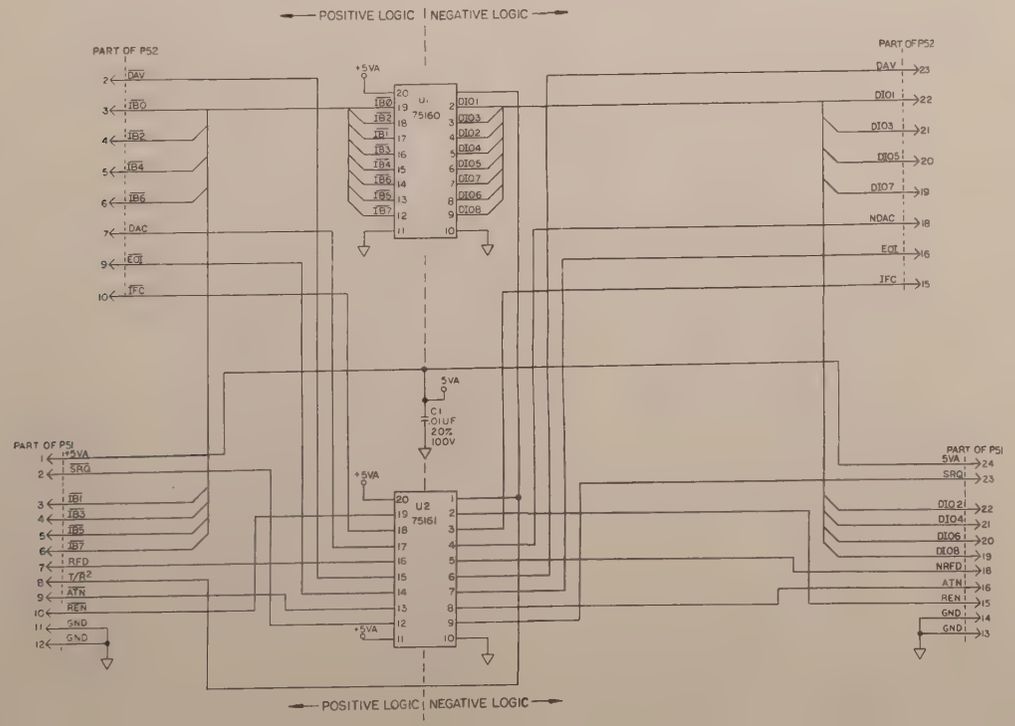
SHEET OF

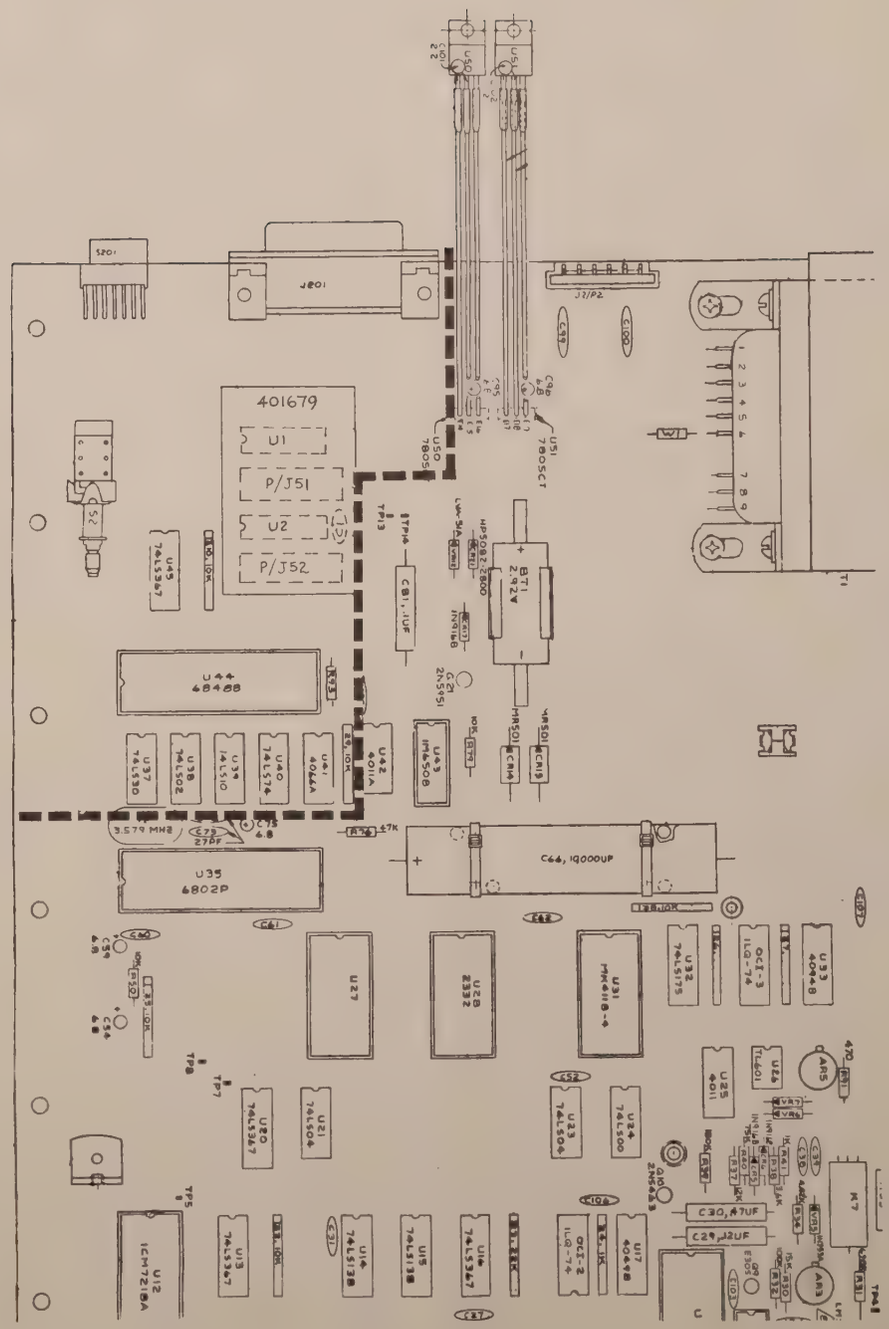
401642 – Assy., PCB, MOTHERBOARD (GPIB)

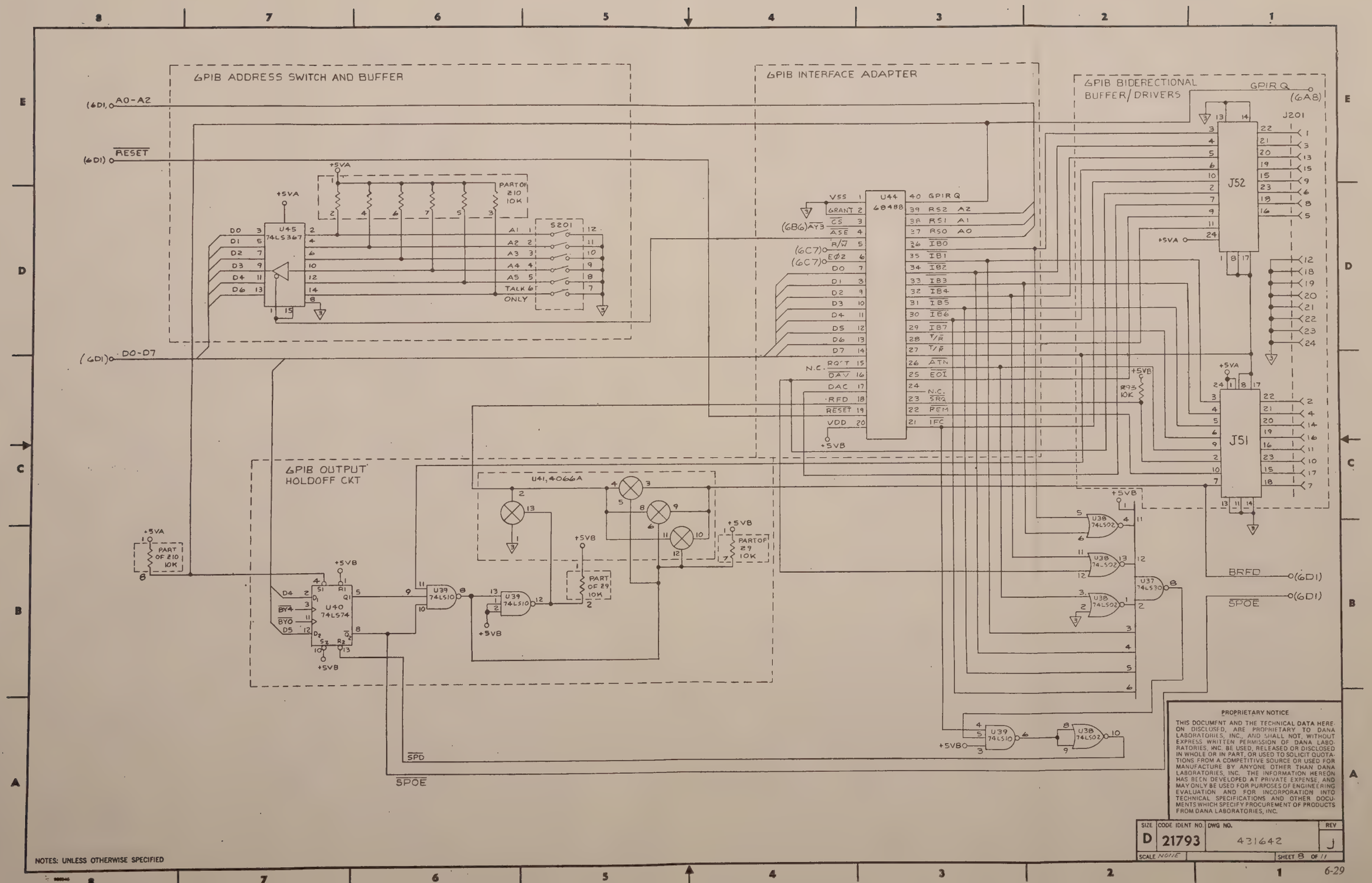
| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| R93 | 000103 | RES CARBON 10K 5% 1/4W | 81349 | RC07GF103J |
| S201 | 600814 | SWITCH 6 SPST | 11237 | 206-6 |
| U37 | 230402 | IC | 27014 | 74LS30N |
| U38 | 230306 | IC QUAD, 2 INPUT NOR GATES | 01295 | SN74LS02 |
| U39 | 230248 | IC POSITIVE NAND GATE | 01295 | SN74LS10N |
| U40 | 230194 | IC 14 DIP, DUAL D FLIP-FLOP | 01295 | SN74LS74N |
| U41 | 230247 | IC MOS BILATERAL SWITCH | 21793 | 230247 |
| U44 | 230430 | IC | 04713 | MC68488L |
| U45 | 230330 | IC | 01295 | 74LS367 |
| Z9 | 080020 | RES CERMET 10 K Network 8P,7R 2% | 11236 | 750-81-R10KΩ |
| Z10 | 080020 | RES CERMET 10 K Network 8P,7R 2% | 11236 | 750-81-R10KΩ |

401679 - GPIB BUFFER ADAPTOR

| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| C1 | 100017 | CAP CERAM .01 MFD 100V 20% | 56289 | C023B101F103M |
| U1 | 230459 | IC | 27014 | μA7924CT |
| U2 | 230472 | IC SN75161 | 01295 | SN75161 |




GPIB ADDRESS SWITCH AND BUFFER
GPIB INTERFACE ADAPTER
GPIB BIDERECTIONAL BUFFER/DRIVERS
GPIB OUTPUT HOLDOFF CKT
(6D1, A0-A2
(6D1) RESET
(6D1) D0-D7
U45 74LS367
U44 68488
U40 74LS574
U41, 4066A
S201
J201
J52
J51
GPIRQ (6A8)
BRFD (6D1)
SPOE (6D1)
SPD
SPOE
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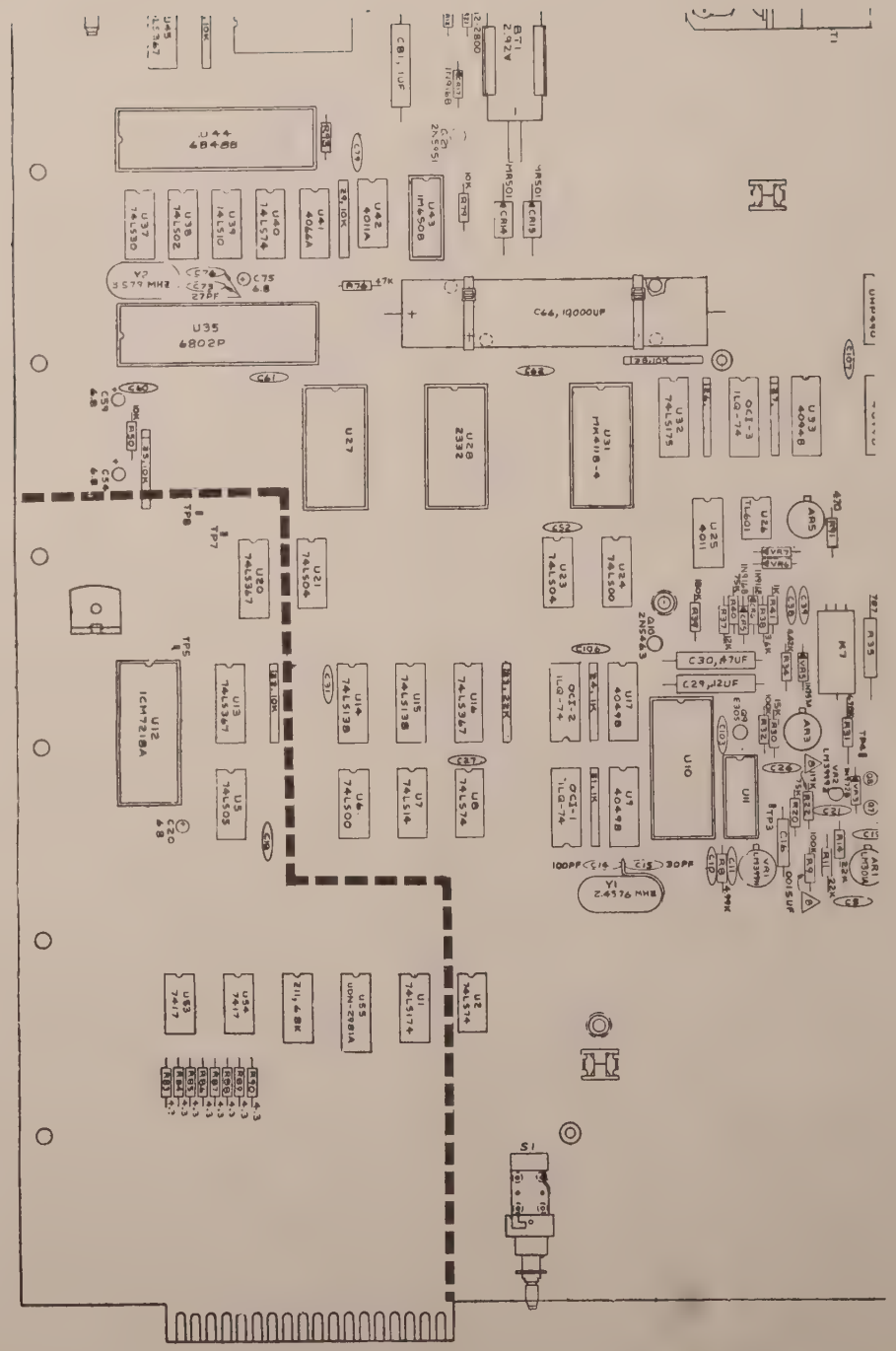
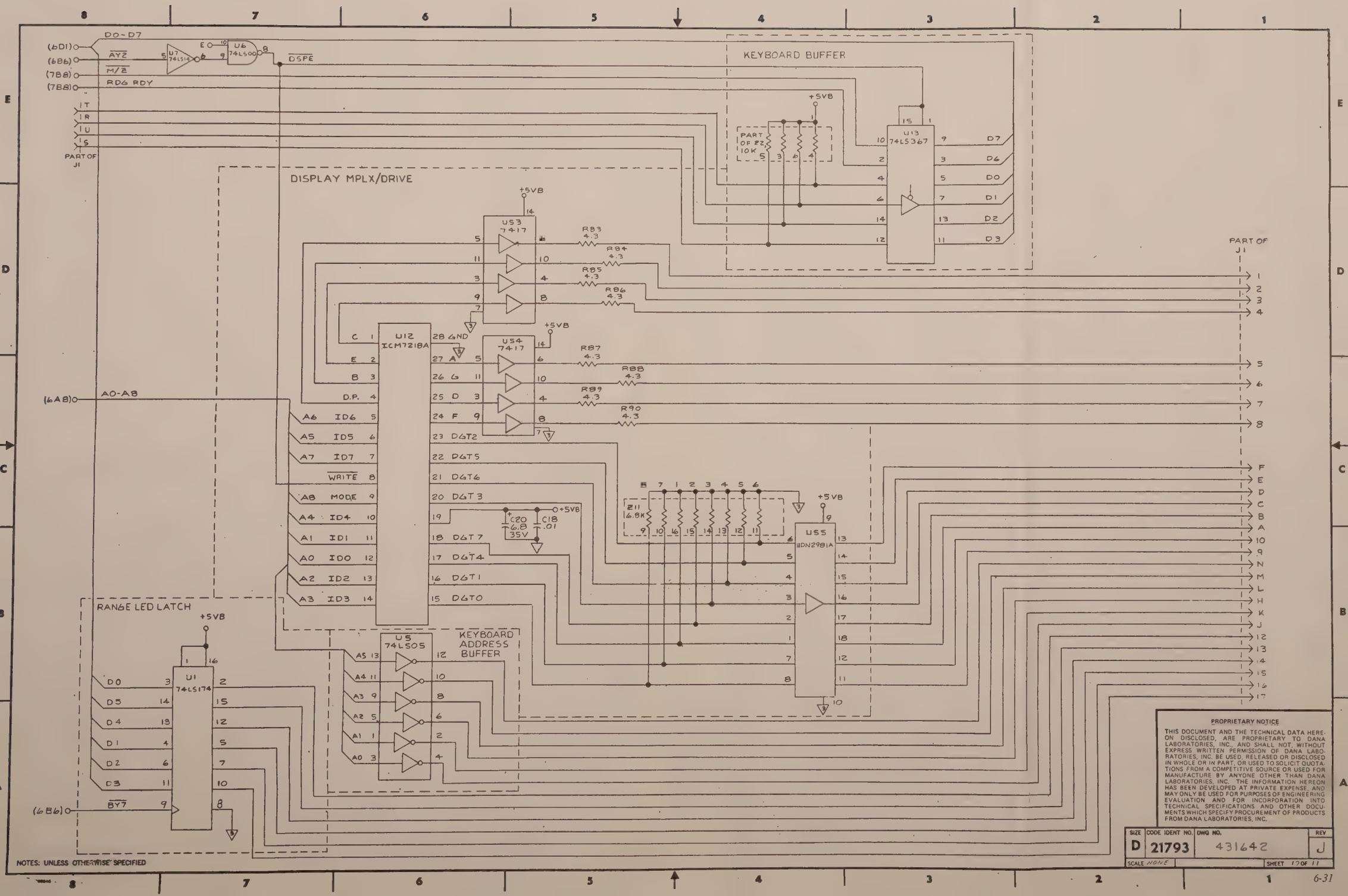
SIZE D
CODE IDENT NO. 21793
DWG NO. 431642
REV J
SCALE NONE
SHEET 8 OF 11
NOTES: UNLESS OTHERWISE SPECIFIED
6-29

401642 – Assy., PCB, MOTHERBOARD (LED DISPLAY)

| REF DES | RACAL-DANA P/N | DESCRIPTION | | | | | FSC | MANU P/N |
|---|---|---|---|---|---|---|---|---|
| C18 | 100017 | CAP | CERAM | .01 MFD | 100 V | 20% | 56289 | C023B101F103M |
| C20 | 110126 | CAP | TANTA | 6.8 MFD | 35 V | 20% | 05397 | T368B685M035AS |
| R83 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R84 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R85 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R86 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R87 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R88 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R89 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| R90 | 001895 | RES | CC | 4.3 OHMS | | 5% 1/4W | 81349 | RC07GF4R3J |
| U1 | 230366 | IC | | | | | 27014 | DM74LS174N |
| U5 | 230192 | IC | 14 DIP, INVERTER | | | | 01295 | SN74LS05N |
| U12 | 230457 | IC | LED DRIVER | | ICM7218A | | 50579 | ICM7218A |
| U13 | 230330 | IC | | | | | 01295 | 74LS367 |
| U53 | 230105 | IC | | | | | 01295 | SN7417 |
| U54 | 230105 | IC | | | | | 01295 | SN7417 |
| U55 | 230483 | IC | DRIVER | | UDN-2981A | | 56289 | UDN-2981A |
| Z2 | 080020 | RES | CERMET | 10 K | Network 8P,7R | 2% | 11236 | 750-81-R1KΩ |
| Z11 | 080009 | RES | CERMET | 6.8 K | Network 16P,8R | 2% | 11236 | 761-3-R6.8K |







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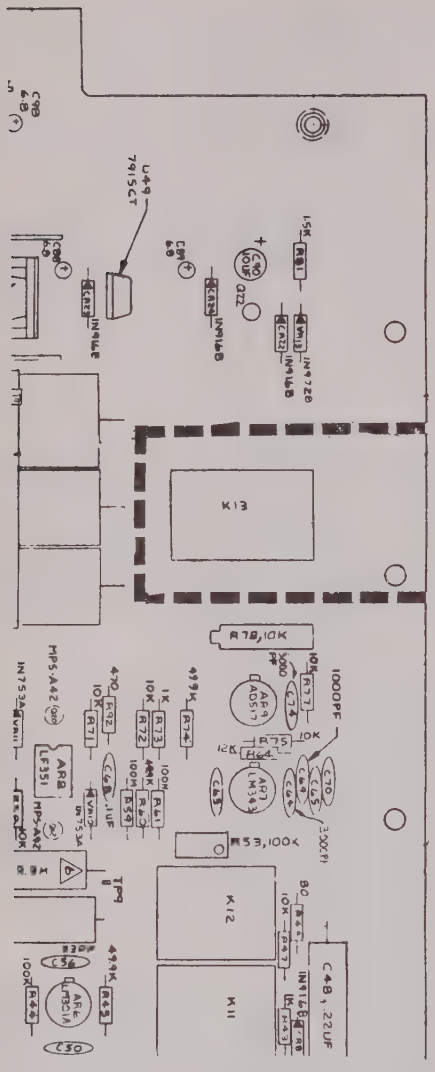
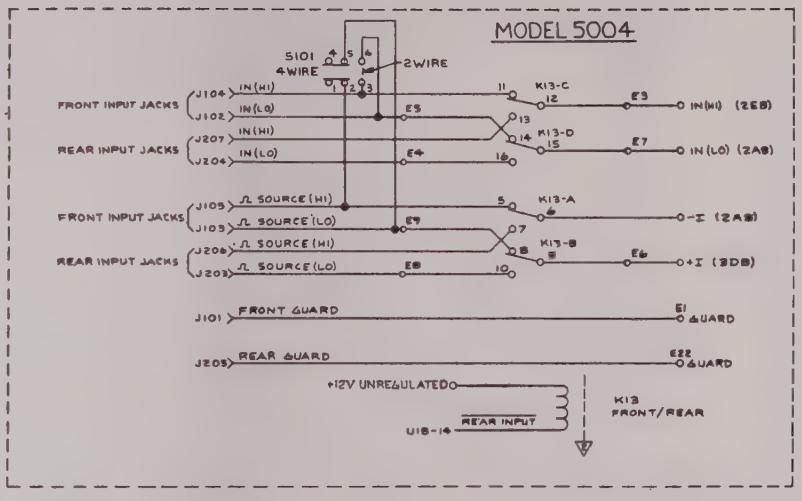
| SIZE | CODE IDENT NO. | DWG NO. | REV |
|---|---|---|---|
| D | 21793 | 431642 | J |
| SCALE NONE | | SHEET 12 OF 11 | |




401642 – Assy., PCB, MOTHERBOARD (F/R SWITCH RELAY)

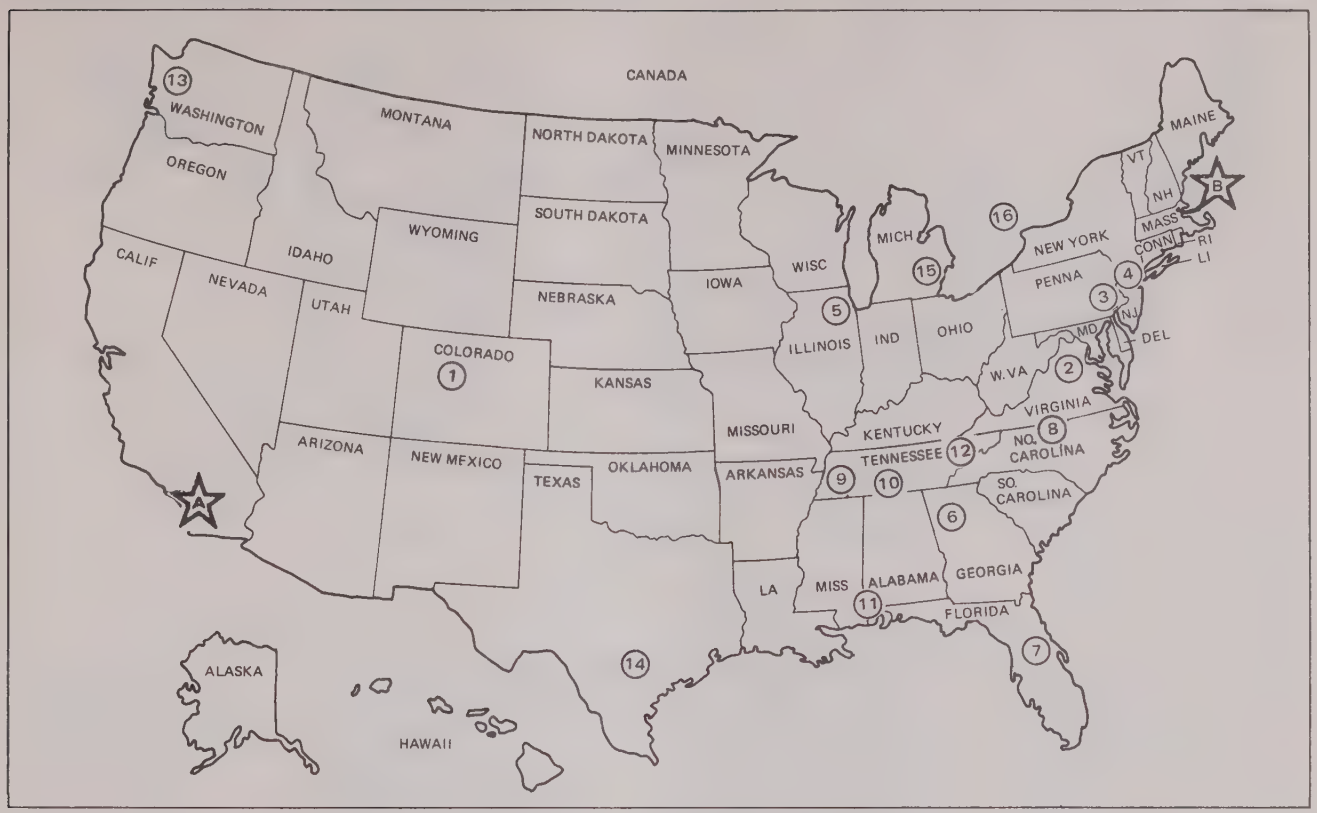
| REF DES | RACAL-DANA P/N | DESCRIPTION | FSC | MANU P/N |
|---|---|---|---|---|
| K13 | 310146 | RELAY, CRADLE 4 FORM C | 26806 | AZ421-08-204 |

## Table 6.1 - List of Suppliers

| FSC | NAME |
|---|---|
| 00779 | AMP, INC.<br>HARRISBURG, PENNSYLVANIA |
| 01121 | ALLEN BRADLEY CO.<br>MILWAUKEE, WISCONSIN |
| 01295 | TEXAS INSTRUMENTS, INC.<br>DALLAS, TEXAS |
| 02660 | AMPHENOL CORP.<br>BROADVIEW, ILLINOIS |
| 03888 | PYROFILM CORP.<br>WHIPPANY, NEW JERSEY |
| 04222 | AEROVOX CORP.<br>(HI-Q DIV.)<br>MYRTLE BEACH, SO. CAROLINA |
| 04713 | MOTOROLA, INC.<br>(SEMI-CONDUCTOR PRODUCTS DIV.)<br>PHOENIX, ARIZONA |
| 05276 | POMONA ELECTRONICS CO., INC.<br>POMONA, CALIFORNIA |
| 05397 | UNION CARBIDE CORP.<br>(MATERIALS SYSTEMS DIV.)<br>CLEVELAND, OHIO |
| 07716 | TRW ELECTRONIC COMPONENTS<br>(IRC)<br>BURLINGTON, IOWA |
| 08257 | NPC ELECTRONICS<br>CANOGA PARK, CALIFORNIA |
| 09023 | CORNELL-DUBILIER ELECTRONICS<br>SANFORD, NO. CAROLINA |
| 11236 | CTS OF BERNE, INC.<br>BERNE, INDIANA |
| 11237 | CTS KEENE, INC.<br>PASO ROBLES, CALIFORNIA |
| 18722 | RCA<br>(INDUSTRIAL TUBE & SEMICONDUCTOR DIV.)<br>MOUNTAIN TOP, PENNSYLVANIA |
| 21551 | C-F ELECTRONICS, INC.<br>VAN NUYS, CALIFORNIA |
| 21793 | RACAL-DANA INSTRUMENTS INC.<br>IRVINE, CALIFORNIA |
| 24355 | ANALOG DEVICES<br>NORWOOD, MASSACHUSETTS |
| 26806 | AMERICAN ZETTLER, INC.<br>COSTA MESA, CALIFORNIA |
| 27014 | NATIONAL SEMI-CONDUCTOR CORP.<br>SANTA CLARA, CALIFORNIA |
| 27264 | MOLEX PRODUCTS CO.<br>DOWNERS GROVE, ILLINOIS |
| 27556 | IMB ELECTRONIC PRODUCTS, INC.<br>SANTA FE SPRINGS, CALIFORNIA |
| 27777 | VARO ELECTRAN DEVICES, INC.<br>GARLAND, TEXAS |
| 32293 | INTERSIL, INC.<br>CUPERTINO, CALIFORNIA |
| 50088 | MOSTEK CORP.<br>CARROLLTON, TEXAS |
| 50434 | HEWLETT-PACKARD CO.<br>(HPA DIV.)<br>PALO ALTO, CALIFORNIA |
| 50579 | LITRONIX, INC.<br>CUPERTINO, CALIFORNIA |
| 50857 | DIONICS, INC.<br>WESTBURY, NEW YORK |
| 56289 | SPRAGUE ELECTRIC CO.<br>N. ADAMS, MASSACHUSETTS |
| 71471 | AEROVOX CORP.<br>(CINEMA PLANT)<br>MONCKS CORNER, SO. CAROLINA |
| 71590 | CENTRALAB ELECTRONICS<br>MILWAUKEE, WISCONSIN |
| 71707 | COTO-COIL CO., INC.<br>PROVIDENCE, RHODE ISLAND |
| 71785 | TRW ELECTRONIC COMPONENTS<br>(CINCH DIV.)<br>ELK GROVE VILLAGE, ILLINOIS |
| 72982 | ERIE TECHNOLOGICAL PRODUCTS, INC.<br>ERIE, PENNSYLVANIA |
| 73138 | BECKMAN INSTRUMENTS, INC.<br>FULLERTON, CALIFORNIA |
| 75915 | LITTELFUSE, INC.<br>DES PLAINES, ILLINOIS |
| 80131 | ELECTRONICS INDUSTRIES ASSOC.<br>WASHINGTON, D.C. |
| 81349 | MILITARY SPECIFICATION |
| 82389 | SWITCHCRAFT, INC.<br>CHICAGO, ILLINOIS |
| 86884 | RCA<br>(ELECTRONICS COMPONENTS DIV.)<br>HARRISON, NEW JERSEY |
| 90201 | MALLORY CAPACITOR CO.<br>INDIANAPOLIS, INDIANA |
| 91637 | DALE ELECTRONICS, INC.<br>COLUMBUS, NEBRASKA |

# RACAL-DANA Instruments Inc.

## U.S. AND CANADIAN SERVICE CENTERS




## AUTHORIZED SERVICE CENTERS

**(1) BALL AEROSPACE SYSTEMS DIVISION**
P.O. Box 1062 — P.O. Box Zip 80306
Boulder Industrial Park
Boulder, Colorado 80302
Telephone: (303) 441-4786

**(2) AMERICAN ELECTRONIC LABORATORIES**
2901 Telestar Court
Falls Church, Virginia 22042
Telephone: (703) 573-8240

**(3)** P.O. Box 552
Lansdale, Pennsylvania 19446
Telephone: (215) 822-2929
SHIP TO: 306 Richardson
Montgomeryville, Pennsylvania 18936

**(4) AMPOWER ELECTRONIC INSTRUMENT CO., INC.**
26 Just Road
Fairfield, New Jersey 07006
Telephone: (201) 227-7720
TWX: 710-734-4387

**(5) COMTEL/PIVAN ENGINEERING**
3535 W. Peterson Avenue
Chicago, Illinois 60659
Telephone: (312) 539-4838
TWX: 910-221-0177

**(6) BROWNELL-ELECTRO**
3020 Commerce Way
Atlanta, Georgia 30354
Telephone: (404) 762-5181

**(7)** 307 27th Street
Orlando, Florida 32806
Telephone: (305) 843-6775

**(8)** 5141 Belhaven Blvd.
Charlotte, North Carolina 28216
Telephone: (704) 394-4341

**(9)** 3053 Tranquility Drive
Memphis, Tennessee 38116
Telephone: (901) 332-9258

**(10)** 1050 Acorn Drive
Nashville, Tennessee 37210
Telephone: (615) 889-8230

**(11)** 3450 Armour Drive
Mobile, Alabama 76607
Telephone: (205) 479-8581

**(12)** 207 Center Park Drive
Knoxville, Tennessee 37922
Telephone: (614) 966-3441

**(13) XTEK**
14824 N. E. 31st Circle
Redmond, Washington 98052
Telephone: (206) 885-6969

**(14) RHODES-GROOS LABORATORIES**
3409 Andtree Blvd.
Austin, Texas 78724
Telephone: (512) 928-0813

**(15) COMTEL STANDARDS LABORATORY**
21186 Bridge Street
P.O. Box 5034
Southfield, Michigan 48037
Telephone: (313) 358-2500

**(16) WEBSTER INSTRUMENTS LTD.**
1200 Aerowood Drive, Unit 28
Mississauga, Ontario
Canada L4W 2S7
Telephone: (416) 625-0600
TWX: 610-492-4560

## FACTORY SERVICE LOCATIONS

**(A) RACAL-DANA INSTRUMENTS INC.**
18912 Von Karman Avenue
Irvine, California 92715
Telephone: (714) 833-1234

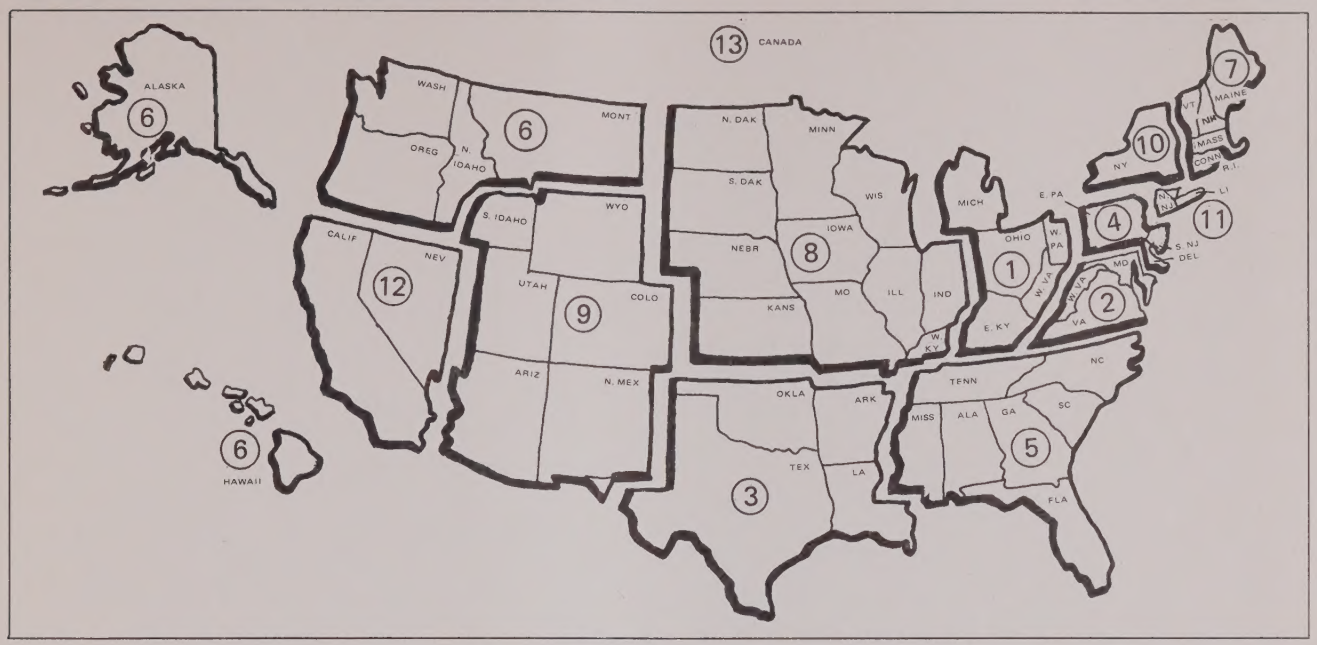
**(B) PAT JENKS ASSOCIATES**
607 North Ave., Door 16
Wakefield, Massachusetts 01880
Telephone: (617) 246-1590

PRODUCT SERVICE TWX 910-595-1136

7-80

# RACAL-DANA Instruments Inc.

## U.S. REPRESENTATIVES




### (1) CARTER, McCORMIC & PEIRCE, INC.

23995 Freeway Park Drive
Farmington, Michigan 48024
Telephone: (313) 477-7700
TWX: 810-242-2986

22650 Lorain Road
Fairview Park, Ohio 44126
Telephone: (216) 779-5100
TWX: 810-427-9253

4977 Northcutt Place
Behnken Building, Suite 116
Dayton, Ohio 45414
Telephone: (513) 222-7700
TWX: 810-459-1613

409 Beatty Road
Monroeville, Pennsylvania 15146
Telephone: (412) 372-4415
TWX: 710-797-3671

### (2) CREATIVE MARKETING ASSOC.

6845 Elm, Suite 107
McLean, Virginia 22101
Telephone: (703) 893-6612
TWX: 710-833-0310

### (3) DATA MARKETING ASSOC.

3330 Bering Drive
Houston, Texas 77057
Telephone: (713) 780-2511
TWX: 910-881-2569

14235 Proton Road
Dallas, Texas 75240
Telephone: (214) 661-0300
TWX: 910-860-5483

833 Isom Road
San Antonio, Texas 78216
P.O. Box 17928
San Antonio, Texas 78217
Telephone: (512) 342-3031
TWX: 910-871-1033

2401 N.W. 39 Expressway, Suite 103
Oklahoma City, Oklahoma 73112
Telephone: (405) 528-6071
TWX: None

300 Huntland Avenue, Suite 233
Austin, Texas 78752
Telephone: (512) 451-5174
TWX: None

### (4) EASTERN INSTRUMENTATION OF PHILADELPHIA

Neshaminy Plaza Bldg. 2, Suite 114
Street Road & Bristol Pike
Bensalem
Pennsylvania 19020
Telephone: (215) 245-6660
TWX: 510-667-1581

### (5) SABER ASSOCIATES, INC.

2051 N.W. 17th Lane
Pompano Beach, Florida 33064
Telephone: (305) 973-8804
(800) 327-8998
(800) 432-5618
(FL. Only)

P.O. Box 517
Rockledge, Florida 32955

P.O. Box 100
Longwood, Florida 32750

P.O. Box 1763
Bradenton, Florida 33506

P.O. Box 21563
Columbia, South Carolina 29221

P.O. Box 6122
Huntsville, Alabama 35802

P.O. Box 888241
Dunwoody, Georgia 30338

### (6) PACIFIC NORTHWEST ELECTRONICS

14264 S.E. Eastgate Way
Bellevue, Washington 98007
Telephone: (206) 641-6444
TWX: None

2035 S.W. 58th Street
Portland, Oregon 97221
Telephone: (503) 292-3505
TWX: None

### (7) PAT JENKS ASSOCIATES

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TWX: 710-348-6559

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TWX: 910-743-4172

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TWX: 810-341-3308

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Telephone: (612) 835-3060
TWX: 910-576-2982

3055 North Brookfield Road
Brookfield, Wisconsin 53005
Telephone: (414) 786-1940
TWX: None

204 Collins Rd., N.E.
Cedar Rapids, Iowa 52402
Telephone: (319) 377-9434
TWX: 910-525-1308

### (9) PLS ASSOCIATES, INC.

7755 E. Quincy Avenue, T-9
Denver, Colorado 80237
Telephone: (303) 773-1218
TWX: None

4300 H Silver Avenue, S.E.
Albuquerque, New Mexico 87108
Telephone: (505) 255-2330
TWX: None

### PLS ASSOCIATES continued

4001 N. 31st Ave., Ste. 61
Phoenix, Arizona 85017
Telephone: (602) 279-1531
TWX: None

2520 South State, Suite 102
Salt Lake City, Utah 84115
Telephone: (801) 466-8729
TWX: None

### (10) SDM REPRESENTATIVES, INC.

673 Panorama Trail West
Rochester, New York 14625
Telephone: (716) 381-9962
TWX: None

15 Fairview Terrace
Paramus, New Jersey 07652
Telephone: (201) 368-0123
TWX: 710-990-5168

### (11) SET MARKETING, INC.

287 Northern Blvd.
Great Neck, New York 11021
Telephone: (516) 466-0550
TWX: 510-223-0833
(Metropolatin New York)

### (12) RACAL-DANA INSTRUMENTS INC.

Northwest Regional Office
1400 Coleman Ave., Suite G-27
Santa Clara, California 95050
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(213) 628-8825
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### (13) WEBSTER INSTRUMENTS LTD.

1200 Aerowood Drive
Unit 28
Mississauga, Ontario
Canada L4W 2S7
Telephone: (416) 625-0600
TWX: 610-492-4560

MP MASTER
MA30569